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NAVAIRDEVCEN DYNAMIC FLIGHT SIMULATOR F-14 SPIN SIMULATION PROGRAM SYSTEM DESCRIPTION AND SPECIFICATION REPORT

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Aircraft and Crew Systems Technology Directorate
Software and Computer Directorate

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This report describes the dynamic flight simluator (DFS) aerodynamic modeling, software, and hardware system description and specifications. The DFS utilizes the NAVAIRDEVCEN centrifuge as a motion base system and includes a multipurpose cockpit crewstation, a cockpit/computer interface system, instrumentation cockpit displays, flight controls, panels, switches, indicators and a number of digital, analog, display and general purpose computers. The initial program planned for the DFS, will investigate problem areas regarding the out-of-control losses of the F-14 aircraft.

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FORWARD

The NAVAIRDEVCEN Dynamic Flight Simulator System Description and Specification Report is the result of an effort to expand the functional requirements information documented in the NAVAIRDEVCEN F-14 Spin Simulation Program Proposal Report, 1 August 1979 (reference a) and to provide detailed functional requirements and/or specifications for the simulator. The Dynamic Flight Simulator System Review Committee Members who were tasked to write this report are listed below along with the area of responsibility assigned to each:

Richard Crosbie (60B) - Committee Chairman
William Mulley (6022) - Systems Review
Jacob Eyth (6022) - Systems Review and Report Coordination
Lloyd Hitchcock (6022) - System Human Factors
G. Terry Thomas (5012) - System Hardware and Report Coordination
John Ryan (6022) - System Interface Hardware
Philip Brickman (5012) - System Software
Dennis Kiefer (8121) - Crew Station Drive Equipment and Interface
Jacques Etkowicz (5022) - Digital Interface Hardware
J. Mark Stifel (6053) - Flight Dynamics

SUMMARY

INTRODUCTION

The NAVAIRDEVCEN is in the process of developing a Dynamic Flight Simulator (DFS) utilizing the unique features of its human centrifuge, illustrated in Figure 1, as a motion base. When completed, the facility will provide the Tri-Service community with the only flight simulator capable of reproducing the total multi-stress environment of actual flight, including sustained g. Using the DFS, advanced concepts in flight control, pilot procedures, cockpit displays, seating configurations, restraint systems, aircraft aerodynamic configurations, engine thrust, etc., can safely and statistically be evaluated in a realistic flight environment. The debilitating and disorienting effects of rapidly applied multi-directional, sustained accelerations which will be available in the DFS are generally omitted in most pre-flight evaluations.

This report describes the hardware and software configuration of the DFS as it is currently envisioned. The equipment/software specifications included herein are intended to be used as guidelines for future procurement. Where applicable, the names of particular equipment manufacturers are used to identify equipment which has already been procured or is under contract.

The last two sections of the report contain the program Work Breakdown Structure (3.0) and Critical Issues (4.0) respectively. Critical Issues are identified as those problem areas which may affect the success of the program if not resolved in a timely and satisfactory manner.

The DFS system description and specification report contains design information that was available as of the publication date. Future revisions will incorporate additional system refinements as they become available.

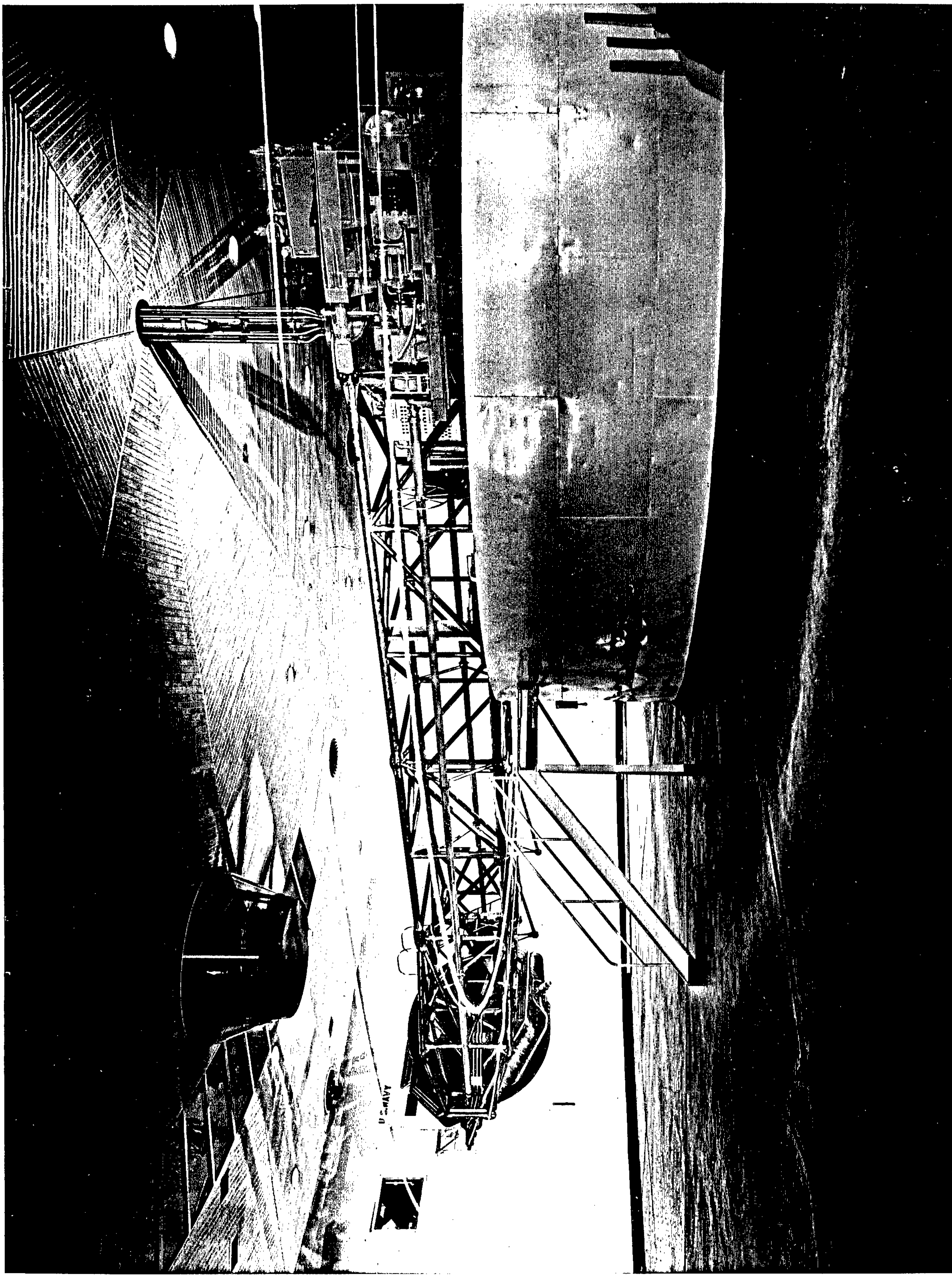


FIGURE 1. DYNAMIC FLIGHT SIMULATOR HUMAN CENTRIFUGE

BACKGROUND

The NAVAIRDEVCEN centrifuge consists of a tubular steel arm, 50 feet long, which is rotated in a horizontal plane about the axis of a vertically mounted 4,000 nominal horsepower direct current motor. A 10-foot diameter centrifuge gondola, located at the end of the arm, is capable of accommodating the crewstation and subject pilot and as a result of its gimballing action is capable of producing almost any force vector through human tolerance, varying from short duration to long term sustaining accelerations.

The NAVAIRDEVCEN Human Centrifuge Facility was constructed in 1952 as an acceleration facility to be utilized for:

- o Medical Research
- o Psycho-Psychological Studies

It was proved useful in the Space Program (1959-64) for:

- o Human Engineering Studies
- o Astronaut Training

In recent years the NAVAIRDEVCEN Human Centrifuge has been utilized primarily for (1) psycho-physiological studies on the effects of combined stress on Naval aircrews and (2) military and commercial aircraft simulation studies.

Specific centrifuge programs involving the dynamic simulation of aircraft included:

1. Simulation and effects of severe turbulence on jet airline pilots.

2. Evaluation of a carrier takeoff director system in simulated night catapult launching of the A-7 aircraft.

3. Dynamic Spin Simulation of F-4/F-14 aircraft.

4. Integrated simulation of atmospheric pressures and dynamic forces during accidental decompression and subsequent emergency descent of high altitude transport aircraft.

The performance and results of these studies have indicated certain centrifuge limitations. These limitations identified the requirements for:

- o Digital Computer computational capability
- o Cockpit display generation and online data acquisition/reduction
- o Improved real-world visual cues
- o Aero data at high angle of attack
- o Variable force pilot stick control loader system

- o Improved centrifuge control drive algorithms
- o Improved control console
- o Solid state hybrid computer
- o Gimbal hydraulic drive (1st and 2nd axis)
- o Gondola third axis drive.

The identification of these deficiencies served as the impetus for a facilities improvement program which was initiated in FY 79 as part of the Dynamic Flight Simulator Development Program. The following list of improvement tasks, some of which are detailed in this report, are currently being pursued or are in the planning phase:

1. Implement digital computer capability (active).
2. Purchase cockpit display generator and online data acquisition/reduction system (active)
3. Purchase real-world visual display and scene generation system (active).
4. Procure multipurpose cockpit crewstation (active)
5. Procure stick control loader system (active)
6. Improve centrifuge drive algorithms (active)
7. Upgrade centrifuge control console (planned)
8. Purchase solid state hybrid computer (planned)
9. Purchase centrifuge gimbal hydraulic drive for the 1st and 2nd axis (planned)
10. Purchase centrifuge gondola 3rd axis (planned).

SYSTEM DESCRIPTION

The NAVAIRDEVCEN Dynamic Flight Simulator consists of a multipurpose cockpit crewstation, a simulated real-world visual display system, a cockpit/computer interface system, instrumentation, cockpit displays, flight controls, panels, switches, indicators, and a number of digital, analog, display, and general purpose computers.

The DFS is presented in this report as five overlapping functional areas, illustrated in Figure 2. These five areas are described below:

AREA 1 - Data Processing: consists of the NAVAIRDEVCEN CDC 6600 Digital Computer system, several EAl hybrid/analog processors, and a IDIIOM/II Interactive Computer Graphic system.

AREA 2 - The Interface between the Data Processors and the crew Station Drive Equipment. This interface consists of 2 fiber optic cables and their required data link systems, and eight high quality display, 24 coax, and 54 twisted pair cables linking the SCD Simulation area with the ACSTD Simulation area.

AREA 3 - The Crewstation Drive Equipment: consists of the Simulation Control computer, a Redifon SP-2 real world scene generator, three symbol generators, a general purpose analog computer, a Bio-Medical Station, and an Experiment Control Station.

AREA 4 - The Interface between the crewstation drive equipment and the crewstation. This interface consists of the centrifuge slip rings, a signal distribution system, a 1553 multiplex data Bus, a special purpose SP2 visual display interface, and interfaces between the Simulation Control computer and the gondola J-Box, the Bio-Medical Station, and the Experiment Control Station.

AREA 5 - The crewstation: consists of the multipurpose cockpit, the visual display unit, the head-up display unit, two multipurpose cockpit display units, a stick/rudder control loader system, a throttle system, intrumentation, panels, switches, indicators, bio-medical sensors, and a gondola J-Box interface system.

The DFS multipurpose cockpit crewstation, illustrated in Figure 3, will have the flexibility of being configured into a variety of aircraft. The crewstation concept consists of a generic cockpit structure and platform which houses a specific cockpit panel. The cockpit panel and cockpit/computer interface are constructed as a removable drawer. Selected cockpit configuration variables are retained; such as down vision, panel width, and pilot eye to panel dimensions. The multipurpose cockpit/computer interface system utilizes a number of multiplexing techniques to insure compatibility with the centrifuge slip ring wiring complement.

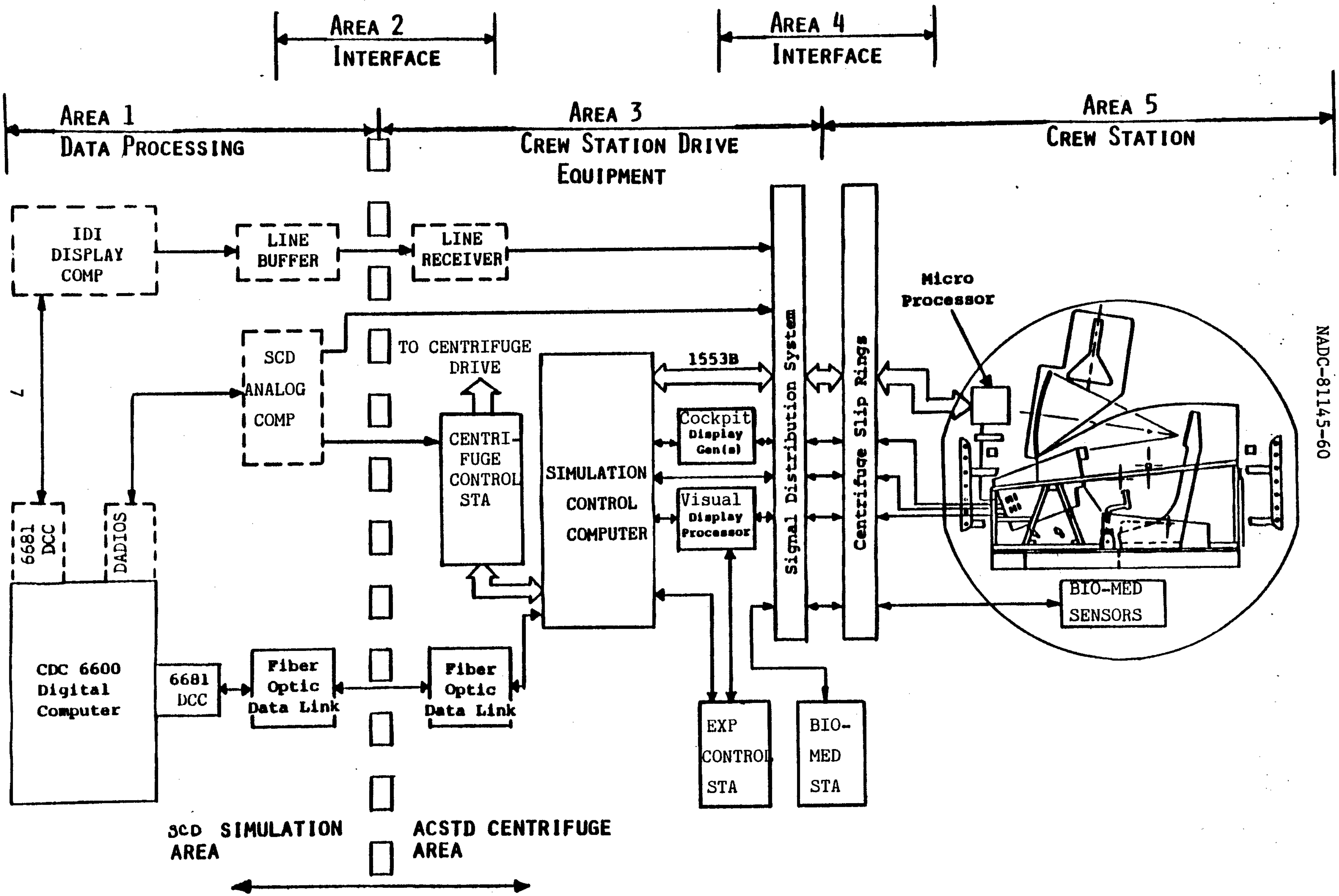


FIGURE 2. DFS HARDWARE EQUIPMENT AND INTERFACE BLOCK DIAGRAM

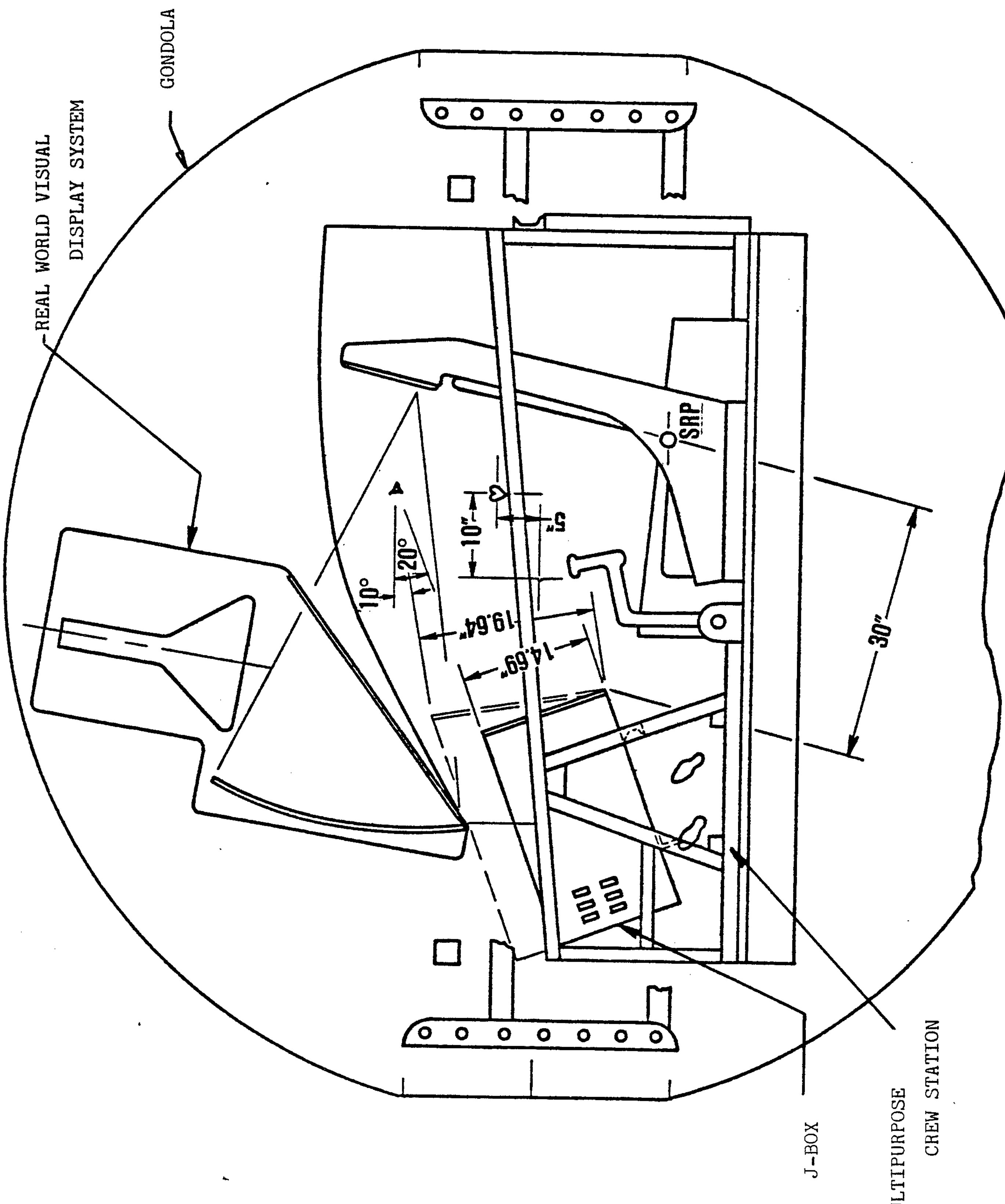


FIGURE 3. MULTIPURPOSE CREWSTATION

The DFS will utilize the Redifon Simulation Company's SP-2 Visual Display System. This system will present to the pilot a three-color, day-brightness, real-world virtual image with 512 edges of computer generated image scene detail. A forward window will provide a 48 degree horizontal by 32 degree vertical field-of-view (FOV). A side window to be installed at a later date will increase the FOV to 96 by 32 degrees. A raster conversion unit will also allow the presentation of the NAVAIRDEVCEN Terrain Model Scene Generator System on the forward window.

The multipurpose cockpit crewstation will include Malwin Company's simulated aircraft intruments, two Collins Company three-color cockpit display systems, a McFadden Company stick/rudder control loader system, and depending on the specific simulated aircraft, a throttle system, head-up display and a number of cockpit panels.

The DFS software development includes flight dynamic aircraft modeling utilizing non-linearized equations of motion, large angle orientations, a digital flight control system, and three-dimensional data storage for all non-linear engine and aerodynamic data. The DFS software will include all aircraft forces and moments, the aerodynamic data package, the digital control system, trim system, and the control algorithms for the centrifuge drive, intrumentation, and visual display system.

It is estimated that the development phase of the Dynamic Flight Simulator Program will be completed in FY-82.

PLANNED EXPERIMENTS

When completed the NAVAIRDEVCEN Dynamic Flight Simulator will provide the Department of Defense with the only fully dynamic flight simulator in which solutions to a wide spectrum of man/machine interface problems can be safely evaluated in the total stress environment of actual flight.

The initial program planned for the DFS will investigate suspected problem areas which contribute to the out-of-control losses of the F-14 aircraft during high angle-of-attack flight. The unique expertise and capabilities required to conduct such a spin program are at the NAVAIRDEVCEN and valuable experience from an earlier F-4/F-14 centrifuge spin program is still resident. The magnitude and duration of the multidirectional accelerations associated with the F-14 aircraft spin problems require that this program be implemented on a simulator with a high sustained g capability. Chuck Sewell, chief test pilot for Grumman Aerospace Corporation stated in reference (b) , "when the F-14 aircraft spin goes flat, the aircraft rotates about 180 degrees a second. The pilot sits about 22 feet forward of the center of gravity, so the feeling is like riding a centrifuge. There are very strong eyeballs out g forces acting on you."

A summary of the experimental tasks which would best utilize the unique capabilities of the DFS are listed below. Included under the tasks are the associated planned/proposed programs.

Primary Mission Tasks (require high sustained g force/motion environment)

1. Survivability and Vulnerability
   - o F-14 Spin Simulation Program.

2. Flight Performance-Transition
   - o V/STOL Flight Transition Program

3. Equipment Test and Evaluation
   - o High Acceleration Cockpit Program
   - o Personnel Restraint System Program
   - o Integrated Protective System Program
   - o Advanced Integrated Display System (AIDS) Program

4. Human Factors Physiological and Environmental
   - o Combined Stress Program

5. Training-Familiarization
   - o F-14 Spin Simulation Program

Other experiments which may be pursued using expanded capabilities of the DFS, but not necessarily involving high sustained g, include:

Secondary Mission Tasks

1. Takeoff and Landing

2. Air Combat Maneuvering

3. Weapon Delivery

4. Human Factors - Task Loading

5. Human Factors - Automatic Decision Aids

CONCLUSIONS

The NAVAIRDEVCEN has the capability of developing a Dynamic Flight Simulator utilizing the human centrifuge to provide a viable impact on solving aircraft mission problems involving rapidly applied and high sustained g environments. This report provides the detailed specifications and/or functional requirements needed for a successful DFS development program.

The completion of the NAVAIRDEVCEN Dynamic Flight Simulator facility will provide the Tri-Service community with the only device short of the aircraft itself in which a pilot can fly a simulated high performance fighter/attack aircraft through its entire flight regime and experience the full effect of the incident force environment.

Critical Issues, detailed in Section 4.0 of this report, must be addressed and a solution found for each in order to realize the optimum performance capabilities of the Dynamic Flight Simulator.

These critical issues include the need for:

a. A detailed System Integration and Test Plan.

b. Detailed experimental procedures to support the F-14 Spin investigation.

c. Control algorithms which provide overall coordination of the simulated aircraft flight control signals with the instrumentation, cockpit displays, real-world visual display system, and the centrifuge motion system so that the pilot does not perceive false cues.

d. The successful adaptation of the visual display system to the high g environment of the Centrifuge Gondola.

e. A wider field of view provided by installing a second-window visual display in the gondola crewstation.

f. The successful implementation of the fiber optic interface link between the CDC 6600 and the simulation control computer.

g. Additional air conditioning capacity in the Experiment Control Station.

h. Additional air conditioning capacity in the centrifuge gondola crewstation.

i. The successful adaptation of the centrifuge slip rings to support intersystem 1553 multiplex communication and video transmission.

j. The implementation and pilot acceptability of a newly developed centrifuge control algorithm.

k. The successful implementation of digital control techniques to the operation of the centrifuge.

l. The validation of the F-14 aerodynamic data package.

m. The validation of the real-time capability of the Simulation Control Computer (Sperry Univac V-77).

n. Aero data for F-14 manual wing sweep configurations.

RECOMMENDATIONS

The NAVAIRDEVCEN Dynamic Flight Simulator System Description and Specification Report should be utilized to procure the required simulator hardware equipment, model and program the required data processing and crewstation drive equipment, and generate the detailed F-14 Spin Simulation experimental designs.

It is anticipated that all of the Critical issues will be solved during the evolution of the Dynamic Flight Simulator. The timely solution of the problems however, will depend on adequate financial support and high priority from in-house contractural and Public Works activities.

It is recommended that the DFS program be continued at the current level of development until final checkout and validation which is scheduled for mid-FY 82. At this point, experimental test programs will support the continued operation of the facility.

NAVAIRDEVCEN, DNL, and PMA-241 funding and manpower support for the DFS Development Program should be continued at a level sufficient to achieve final checkout and validation by mid-FY82 in order to meet the urgent need of the F-14 aircraft. From this point on, additional test programs which are now being developed are expected to support the continued operation of the facility.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF ABBREVIATIONS

A	Ampere
A/A	Air-to-Air
ac	Alternating Current
ACM	Air Combat Maneuver
ACSTD	Aircraft & Crew System Technology Directorate
A/D	Analog to Digital
ADF	Automatic Direction Finder
AFB	Air Force Base
AFCS	Automatic Flight Control System
A/G	Air-to-Ground
AOA	Angle of Attack
ARI	Aileron-Rudder Interconnect
A/S I	Airspeed Indicator
AUG	Augmentation
AUTO	Automatic
AWL	All Weather Landing
BAI	Barometric Altitude Indicator
BAR	Barrier
BDHI	Bearing Distance Heading Indicator
BIC	Buffer Interlace Controller
BTC	Block Transfer Controller
CC	Computer Controlled
CCS	Central Computer System
CCW	Counter Clockwise
CDC	Control Data Corporation
cg	Center of Gravity
CGI	Computer Generated Image
CM	Central Memory
CP	Central Processor
CPU	Central Processor Unit
CRC	Cyclic Redundancy Check
CRT	Cathode Ray Tube
CSEF	Crew Station Evaluation Facility
D/A	Digital to Analog
DADIOS	Direct Analog/Discrete Input/Output Systems
DASMR	Sperry Univac Assembly Language
dc	Direct Current
DCC	Data Channel Converter
DFS	Dynamic Flight Simulator
D/L	Data Link
DMA	Direct Memory Access
EAI	Electronic Associates Inc.
ECG	Electrocardiograph
ECM	Electronic Counter Measures
ECS	Extended Core Storage
ESS	Electronic System Simulator

FIFO	First in, First out
FOV	Field of View
F.S.	Full Stop
g	Acceleration of the force of gravity, 32 ft/sec^2
G	Centrifuge g vector
GR	Radial g force
GT	Tangential g force
HRTM	Hardware real-time monitor
HSD	Horizontal Situation Display
Hz	Hertz, cycles/second
IC	Initial Conditions
ICS	Intercommunications
ID	Indiscrete
IDI	Information Display Inc.
IDIIOM	Information Display Inc. Input/Output Machine
IMN	Indicated Mach Number
I/O	Input/Output
IP	Image Processor
K	Thousand
KIAS	Knots, indicated air speed
LDG	Landing
LSI	Large Scale Integration
M	Million
MIL	Military Power
MOS	Metal Oxide Semiconductor
MP	Memory Protection
NADC	Naval Air Development Center
NASA	National Aeronatuics and Space Administration
NATC	Naval Air Test Center
NAV	Navigation
NTSC	National Television System Committee
OD	Outdiscrete
O.D.	Outside Diameter
OFT	Operational Flight Trainer
O.P.	Operating Pressure
PF/R	Power Failure Restart
PIM	Priority Interrupt Module
PIO	Programmed Input/Output
PMA	Priority Memory Access
PP	Peripheral Processor
PPU	Peripheral Processor Units
PROM	Programmable Read Only Memory
PSI	Pounds per square inch

R/C I	Rate of climb indicator
RCVR	receiver
RCT	Required Computer time
REIL	Runway End Identifier Lights
RI	Radio Instrumentation
RIO	Radar Intercept Officer
RMD	Rotating Memory Device
RTC	Real-time clock
RVR	Runway Visible Range
SAS	Stability Augmentation System
SBC	Single board computer
SCC	Simulation Control Computer
SCD	Software and Computer Directorate
STAB	Stability
SUB	Subroutine
TACAN	Tactical Air Navigation System
TDZ	Touchdown Zone
TID	Tactical Indicator Display
TTY	Teletype
TV	Television
UHF	Ultra High Frequency
VASI	Visual Approach Slope Indicator
VDI	Vertical Display Indicator
VTR	Video Tape Recorder
WCS	Writable Control Store

1.0 DYNAMIC FLIGHT SIMULATOR OPERATIONAL TASK REQUIREMENTS

The Dynamic Flight Simulator will be a general purpose facility to be used for investigations of many weapon system problems in the future. It would be an impossible task to attempt to define all future requirements in detail. Therefore, this section will be a combination of specific and general requirements; general requirements where they are known, such as the visual display requirements and specific requirements for the first application, the F-14 spin.

1.1 F-14 Aircraft Flight Characteristics

The F-14 flight characteristics in the stall/spin regime are described in detail in the NATOPS Flight Manual (reference c).

The following section is an excerpt from the F-14 NAVTOPS Manual.

1.1.1 Cruise and Combat Configuration

1.1.1.1 Normal Stall Approaches

In a 1-g deceleration, light buffet starts at 13 to 14 units angle-of-attack (AOA) and increases to a moderate level at about 15 units. After 15 units AOA, buffet intensity varies only slightly with increasing angle-of-attack and provides no usable indication of the aircraft angle-of-attack. At 20 to 28 units AOA, reduced directional stability is apparent, and even small control inputs will cause yaw oscillations that, if unchecked, can produce a mild wing rock ($\pm 10^{\circ}$ to 15°). Stores which are aft of the center of gravity (cg) aggravate the yaw excursion slightly. Above 25 units AOA, lateral stick deflection causes yaw in an opposite direction to the stick deflection. The stick should be centered laterally above 25 units AOA and the rudders used to maintain balanced flight. Rudders are effective in controlling yaw and bank angle at all angles of attack. Large rudder or lateral stick inputs produce an increase in angle-of-attack as sideslip increases, particularly at aft cg locations. If the deceleration is continued to full aft stick deflection, angle-of-attack is equivalent to about 42° to 45°, although the cockpit indicator pegs at 30 units AOA. Pitch attitude is between 10° to 20° above the horizon (no external stores) and 10° to 15° below the horizon (maximum external load). Some longitudinal porpoising may occur at full aft stick. Maneuver slats delay buffet onset to 20 to 21 units AOA and reduce buffet intensity throughout the buffet region. Wing rock at 20 to 28 units AOA will be more severe ($\pm 25^{\circ}$) and more difficult to damp.

1.1.1.2 Accelerated Stall Approaches

Aircraft behavior does not differ significantly from that observed in normal stall approaches. Lateral stick inputs should be avoided above 25 units AOA below Mach 0.5, and above 17 units at Mach 0.5 to 1.0. During

accelerated stall approches at higher g and higher speeds, the rates of adverse yaw and subsequent roll-away increase from the direction of lateral stick deflection. Recovery from accelerated high angle-of-attack flight is the same as for normal stall.

1.1.1.3 Departure From Controlled Flight

A departure from controlled flight in cruise and combat configuration is caused by excessive sideslip and/or yaw rate. Such a departure can occur with lateral and/or directional control inputs or large thrust asymmetry due to a stalled engine at high AOA. At subsonic airspeed, the AOA at which departure occurs decreases as Mach number increases. No departures have been encountered during supersonic flight testing.

Departures usually result from the adverse yaw generated by excessive or prolonged lateral stick deflection in maneuvering flight. These departures can be minimized by using rudder for roll control at high AOA. Above 0.7 IMN, however, abrupt rudder inputs alone may generate sufficient sideslip to induce violent departures. A single engine stall at high AOA produces a powerful yawing moment that may lead to a departure if rapid action to reduce AOA is not undertaken. The departures are characterized by a rapid increase in yaw rate and lateral acceleration either away from the lateral stick deflection, or in the direction of the rudder input or the stalled engine. The yaw rate may develop into a series of uncommanded rolls. The departure may occur as low as 25 units AOA below 0.5 IMN to 17 units AOA at higher speeds. The severity of the departure increases with increasing Mach number. Indicated angle-of-attack remains pegged at 30 units AOA throughout the maneuver. The pilot's natual tendency is to oppose the roll with lateral stick. This aggrevates the departure, especially if the roll SAS is engaged, and should not be done. During air combat maneuvers (ACM) and all other high AOA maneuvering, the aircraft should be flown with generous use of rudders, leading with or using rudder simultaneously with lateral stick deflection. Use maximum rudder, if necessary, to reduce or eliminate adverse yaw. The aircraft is significantly less prone to depart if flown with the wing sweep control in the AUTO position. Manually sweeping the wings aft of the programmed sweep angle significantly reduces the departure resistance of the aircraft. Manually selecting ROLL STAB AUG switch OFF increases departure resistance and reduces the severity of departures once they occur. While maneuver slats increase the departure resistance of the aircraft, neither maneuver flaps nor speed brakes have any noticeable effect on flight characteristics once the aircraft does depart.

Accelerated departures are initially characterized by a rapid increase in lateral acceleration, but may become violently oscillatory about all three axes. Test have shown aircraft displacement rates in excess of 120° per second in roll and 70° per second in yaw, and positive load factors that almost double the g at entry. Pitch rates oscillate up to ±30° per second and lateral acceleration oscillates up to ±0.6g. These oscillations may cause pilot disorientation, and proper recovery controls may not be obvious. If this occurs, the proper response would be to neutralize rudders and lateral

stick and apply forward longitudinal stick. Recovery indications should become apparent within two turns.

Yawing moments may be generated by:

- o Pilot commanded control system inputs (either intentional or unintentional)
- o Uncommanded roll SAS inputs.
- o Thrust asymmetry.

The first two may be minimized by verifying that lateral stick and rudders have been neutralized. Military power should be applied to both engines. This action will provide maximum compressor stall margin; yawing moment resulting from a stalled engine can be neutralized with opposite rudder except at very slow airspeeds. The flightcrew should lock shoulder harnesses as soon as possible into a departure to maintain body position and delay incapacitation.

1.1.2 Flat Spin

A flat spin is recognized by the flat aircraft attitude (approximately 10° nose down with no pitch or roll oscillations), steadily increasing yaw rate, and longitudinal acceleration (eyeballs-out g). It may develop within two to three turns following a departure if yaw is allowed to accelerate without rapid, positive steps to effect recovery. Yaw rate can result from departure induced by aerodynamic controls, a large thrust asymmetry, or a combination of both. The aircraft may first enter an erect oscillatory spiral as airspeed rapidly decreases. Frequent hesitations in yaw and roll may occur as yaw rate increases. The turn needle is the only valid indicator of spin direction. It always indicates turn direction correctly, whether erect or inverted. AOA will peg at 30 units and airspeed will oscillate between 0 and 100 knots. The aircraft may also depart by entering a coupled roll where yaw rate may build up without being noticed to the point that when roll stops, yaw rate is sufficent to sustain a flat spin. A large thrust asymmetry, that is, engine stall at high angle of attack or low airspeed, can also produce sufficient yaw rate to drive the aircraft into a flat spin. In all instances, recovery should be accomplished by prompt application of departure recovery procedures to reduce angle of attack and control yaw rate.

Regardless of the method of entry, once the flat spin has developed, the flat aircraft attitude (10° nose down), steadily increasing yaw rate, and buildup of longitudinal g forces not accompanied by roll and/or pitch rates will be apparent to the flight crew. AOA will be pegged at 30 units, yaw rate will be fast (as high as 180° per second) and altitude loss will be approximately 700 feet per turn. Longitudinal acceleration can reach as high as 6.5g. Time between aircraft departure and flightcrew recognition of a fully developed flat spin depends upon the nature of the entry (accelerated departure, low speed stalled engine, etc.). The time between recognition of a

flat spin and buildup of incapacitating longitudinal g forces is dependent upon aircraft loading, thrust asymmetry, flight control position during spin entry and spin, locked or unlocked harness, tightness of the lap restraints, and flightcrew physical condition and stature. Test data indicate that following recognition of a flat spin, the pilot may be able to maintain antispin controls for 15 to 20 seconds (approximately 7 to 10 turns) but may severly jeopardize his ability to eject due to the incapacitation that occurs as the g forces build. Successful F-14 flat spin recover procedures have not been demonstrated; therefore, once the aircraft is confirmed to be in a flat spin, the flightcrew should jettison the canopy and eject. This decision should not be delayed once the flat spin is recognized.

It is important to understand the longitudinal g forces can be present in accelerated departures from controlled flight and ejection initiated solely because of longitudinal g forces is premature.

To preclude premature ejection from a recoverable aircraft, verify that the aircraft is not rolling or oscillating in pitch or is not in a coupled departure. If any of these characteristics are evident, then a flat spin has not developed and departure recovery procedures should be continued.

1.1.2.1 Departure/Flat Spin Procedures

Stick	FORWARD/NEUTRAL LATERAL
Rudder	OPPOSITE YAW
Throttles	MIL (engine(s) not stalled)
Shoulder harness	LOCK
No recovery	STICK INTO TURN NEEDLE
Recovery indicated	NEUTRALIZE CONTROLS

Recover at 17 units AOA

Flat spin - Verified by flat attitude, increasing yaw rate, increasing longitudinal g forces, and lack of pitch and/or roll rates.

a. Canopy JETTISON
b. EJECT

1.1.3 Vertical Stall Approaches

It the aircraft is allowed to decelerate to zero airspeed in a vertical or near vertical attitude, it will slide backwards momentarily, then pitch down to a near vertical dive. The rate of nosedown pitch is about 20° per second at all wing sweeps up to 50°. Aft of 50°, the pitch rate increases until,

at 68° wing sweep, the pitch rate is about 30° per second. The aircraft may pass through the vertical to near level flight attitude, yaw in one direction, and then return to a vertical dive attitude. This may occur more than once. This tendency is more pronounced at aft wing sweeps, but can usually be controlled with longitudinal control inputs. Some pitchovers may be accompanied by yaw and/or roll, which will dampen without pilot action as the aircraft accelerates. Rudder and lateral stick are also effective in damping oscillations once the aircraft is nose-low and accelerating. The aircraft is very reponsive to longitudinal stick inputs at all angles-of-attack at speeds above 100 KIAS.

1.1.3.1 Vertical Recovery

In a nose-high, rapidly decreasing airspeed condition:

- o At less than 130 KIAS or above 40,000 feet altitude, if in afterburner, leave throttles fixed until recovery is complete.
- o Below 40,000 feet altitude at greater than 130 KIAS, if in afterburner, reduce throttles to MIL as soon as possible and while forward airspeed still exists.
- o Any altitude, throttles are below MIL, advance them to MIL as soon as possible and while forward airspeed still exists.

1. 100 KIAS use longitudinal stick to pitch the nose down. At extreme nose-high attitudes, aft stick facilitates recovery time and will avoid prolonged engine operation with zero oil pressure.
2. Below 100 KIAS, release controls and wait for aircraft to pitch nosedown. This prevents depleting hydraulic pressure if both engines fail, and provides the quickest recovery.
3. If roll and/or yaw develop, wait until aircraft is nosedown and accelerating before correcting with rudder or lateral stick.
4. Use longitudinal control as necessary to keep nose down and accelerate.
5. Above 100 KIAS, pull out, using 17 units AOA.
6. Recovery to level flight from point of pitchover can normally be completed in less than 10,000 feet.

1.1.4 Inverted Stall Approaches

As in normal stall approaches, there is no clearly defined inverted stall. A moderate rate application of full forward stick in inverted flight results in a negative angle of attack of about -30°.

Indicated AOA will show zero beyond about -5° true angle of attack. Lateral stick provides effective roll control and rudders are very powerful in generating yaw and roll at all attainable negative angles of attack. Dihedral effect is negative. Therefore, a right rudder input produces right yaw, but left roll. This feels natural to the pilot in inverted flight, and enables raising a wing with opposite rudder when inverted. Oil pressure will indicate zero and the OIL PRESS caution light and MASTER CAUTION light, will illuminate while at negative angles of attack.

1.1.4.1 Inverted Stall Recovery

Recovery from an inverted stall is performed by applying full aft stick, while neutralizing lateral stick, to return to positive g flight. Recovery from negative g conditions will usually occur immediately. Return to level flight can then be performed from the resulant nosedown attitude by rolling erect with rudder and/or lateral stick and pulling out at 17 units AOA.

1.1.5 Inverted Spin

An inverted spin may be encountered if the stick is moved forward rapidly enough to cause the aircraft to unload while the aircraft has a yaw rate. In contractor tests, the inverted spin has been caused by holding full forward stick while inverted and applying this combination through 180° of roll. The spin appears to be stable (autorotative) in that pro-spin controls need not be held to keep the spin going. The inverted spin has yaw rate opposite to roll rate, but is primarily identified from cockpit instruments by less-than-zero g and an angle of attack of zero. Spin direction must be determined by observing the turn needle deflection, as the inverted spin is quite disorienting. Lateral stick deflection has little effect on inverted spin characteristics. Both engines suffer compressor stalls during the rolling, yawing motions just before becoming inverted.

Inverted spins can be avoided by applying aft stick if the aircraft is unloading while yawing or rolling. Warning of a possible inverted spin occurs sufficiently in advance for the pilot to take corrective action by applying aft stick. Warning is very noticeable in the form of a nosedown pitch with a yawing and possible rolling motion that is quite uncomfortable to the pilot.

1.1.5.1 Inverted Departure and/or Spin Recovery Procedures

Stick	FULL AFT AND NEUTRAL LATERAL
Rudder	OPPOSITE YAW
Throttles	MIL
Recover Indicated	NEUTRALIZE CONTROLS

Recover at 17 units AOA

Altitude loss during the inverted spin is approximately 3000 feet per turn. Time per spin turn is 10 seconds at angles of attack greater than 50°. The engines will encounter compressor stalls regardless of thrust setting. In order to have the greater possible engine stall margin, military thrust should be maintained until a compressor stall occurs. Upon encountering engine compressor stall, the affected engine throttle should be moved rapidly to IDLE to avoid engine overtemperature. If TIT remains high and RPM low, shut down the engine. If both engines have stalled and TIT readings are high even with IDLE selected, shut down only one engine to have hydraulic pressure available for recovery and subsequent flightpath control. After recovery, the shutdown engine can then be restarted and the other engine shut down.

1.2 DFS Control System Requirements

The DFS control system must be capable of reproducing both the geometry and aerodynamic feel of the control systems of air-to-air and air-to-ground combat aircraft. The geometry requirements are defined by MIL-STD-1333A as directed by General Aircraft Specification SD-24K (paragraph 3.7.1.3.1). Though replaced by MIL-STD-1333A, MS33574 provides a generally acceptable summary of control system geometry. The forces which can be exerted by subject pilots may be determined by reference to Van Cott and Kinkade's "Human Engineering Guide to Equipment Design" (Ref d, Page 557). Combining the data from these sources, the following summary statements may be made about the data control system.

1.2.1 Yaw Control

The yaw control should consist of two pedals configured in accordance with MIL-B-8584. The centers of the pedals should be between 7.5 and 10.5 inches from the center line of the aircraft. Optimally, the center of pedals should be adjustable within that range to permit the system to be tailored for an exact fit of a particular aircraft geometry (e.g., F/A-18 = ± 7.7 inches, AV-8B = ± 9.0 inches). The pedals should have a minimum position adjustment capability of 10.0 inches and a travel of at least ± 3.0 inches. The travel should be variable from ± 1.0 inch out to full (± 3.0) travel. The system should be able to provide control forces approximating 50 pounds/inch. Since the 95th percentile force which can be exerted by the foot is approximately 500 pounds, the yaw control system should be able to absorb such a loading without damage to the linkages and/or stops. The ability to lock the rudders at the neutral point and monitor force applied (conversion to a zero-displacement, force system) would be desirable.

1.2.2 Pitch Control

The pitch control should have a throw which is variable from approximately 5.0 to 12.0 inches with a controllable center point within that range. The maximum loading gradient should be at least 35-40 pounds/inch. The stops should be able to withstand forces of at least 200 pounds forward (push) and 130 pounds aft (pull) without damage.

1.2.3 Roll Control

The roll control throw should be adjustable from ± 3.0 inches (for the F/A-18) to ± 7.0 inches (specification maximum). The maximum force gradient should be at least 25 pounds/inch. The roll stops should be able to experience 70 pounds force to either the left or right without damage.

The response rate of the controls in all three axes should not be less than 30 inches/second. All three axes should be designed to reproduce the trim capability present in actual aircraft. The ability to program non-linear control force gradients would be highly desirable. The yaw and pitch systems should be capable of reproducing the "shaker" warning systems used on aircraft to alert the pilot to an impending stall. All three axes must be capable of accepting external force modifications throughout their displacement range. These force adjustments would represent aerodynamic changes in loading (e.g. - control surface masking, etc.). All axes should provide the capability to vary the parameters of break-out force, deadband, friction, damping, and trim rate.

For the safety of the subject pilot within the confines of the gondola, the system should be shielded against high pressure hydraulic leaks. In addition, the controls should not go hard-over rapidly in the event of hydraulic and/or electrical power failure/interruption. The system must be resistant to any degradation imposed by accelerations of up to 10 g, vibrations up to 10 hertz, and the two in combination. The system should be thoroughly protected against electrical shock, keeping in mind the fact that subjects working in a high acceleration environment frequently sweat profusely.

The pitch/roll control system should be capable of accepting alternative control grips. In addition to the trim control, there should be provisions for routing at least 10 signals from the grip to the outside for the simulation of grip control functions (weapon select, bomb select, bomb release, sensor control, etc.).

1.3 DFS Visual System Requirements

The visual system for the DFS will face markedly different requirements as a function of the aspects of flight to be simulated. This section will address three modes; spin, air-to-air combat (A/A), and air-to-ground weapon delivery (A/G). These simulation modes will be considered with respect to the variables of field-of-view, system resolution, and update rates.

1.3.1 Spin Simulation Visual Requirements

The spin simulation poses the least stringent demands upon the visual system. The 48 x 32 degree field-of-view (FOV) of the proposed Redifon Novoview SP-2 system should be more than adequate. The early spin simulations conducted using the centrifuge (refs. e, f and g) provided sufficient out-the-window FOV to permit the pilot to use visual cues to determine pitch, roll, and yaw direction and rates. FOV of the installation used for this study was only 40 x 16 degrees (ref h).

Since the outside world cues used in spin perception can be adequately provided by gross representations of cloud, horizon and land mass, almost no demands are placed upon system resolution. The fact that the proposed system is color capable makes the element of resolution even less critical since most of the visual elements are actually more readily detectable by color than they are by shape (e.g., ground, sky, clouds, etc.).

The update rates for spin must meet more demanding requirements. The system must be able to provide visual cueing of roll and yaw rates up to 200 degrees/second and pitch rates of at least 80 degrees/second. Acceptable fusion of scene motion should be obtainable at refresh rates of 16-20 per second. This requirement is within the capability of the proposed Redifon system (40/sec). However, care must be taken to guard against strobing or other visual phenomena that might distort motion perception at high rates of scene translation. There is no way to determine such a potential for distortions apriori; hardware test is the only sure technique for evaluation. Since there appears to be a basic physiologic velocity estimation mechanism in the human subconscious, the interval required for smooth apparent motion between sequential images becomes greater as the images move further and further apart (Korte's Law). Therefore, it might prove necessary to vary update rate as a function of translational image velocity.

1.3.2 Air-to-Ground Visual Requirements

The FOV specified for the Redifon system should prove adequate for most A/G simulation purposes. The visual simulator used by McDonnell Douglas in their simulations of A-18 and AV-8B weapon delivery has a diagonal FOV of 60°, the equal of the Redifon system. These simulations have been more than adequate so FOV of the centrifuge system should be no problem to comparable simulation efforts.

The update rate should be on the order of 20/second which is within the capability of the proposed system. Again, no strobing or other aberrations should be observable.

The resolution of the Redifon Novoview system is considered only marginally acceptable for A/G simulation. Using the 50 inch spherical mirror proposed for the Redifon system, a 25 inch tube with 600 lines would yield approximately five minutes of visual arc per line (which corresponds to the 5 arc minute resolution claimed for this system). Discrimination of objects presented by a television system is a function of both subtended visual angle and information richness (number of lines). Research has shown that typical A/G targets (bridges, aircraft, buildings, oil tanks, etc.) require from 40 to 60 minutes visual angle (8 - 12 lines) when using a 5 arc minute raster (see Figure 4). Thus, a 30 foot oil tank would be recognizable at a simulated range of 0.34 nautical miles. This is far too low for any type of weapon delivery task involving weapon delivery based upon target recognition.

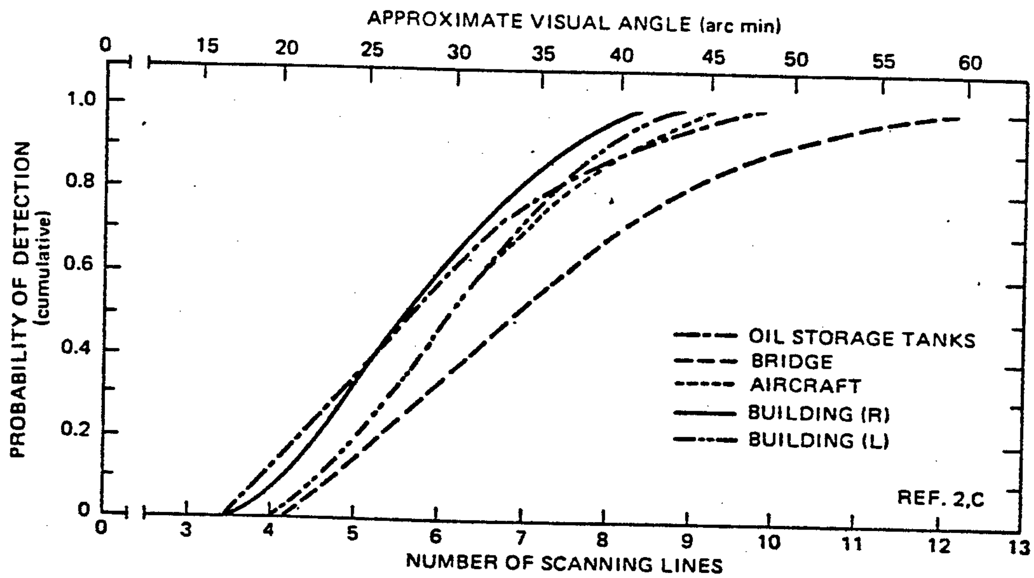


FIGURE 4. TARGET RECOGNITION ON CRT

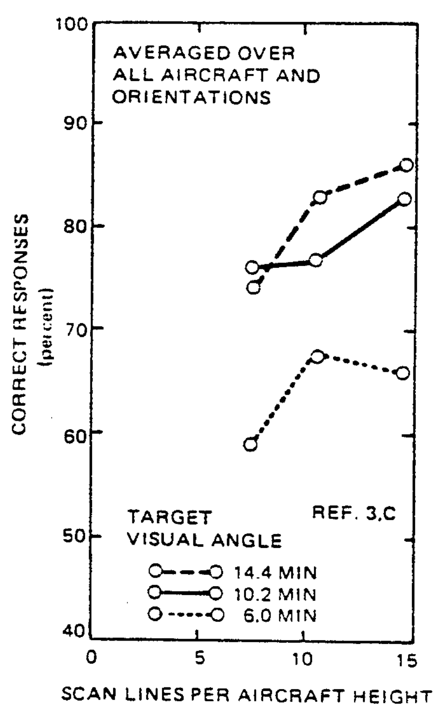


FIGURE 5. AIRCRAFT ORIENTATION RECOGNITION ON CRT

However, in a scenario where the pilot knows he is attacking a tank farm and is receiving guidance to the target with the target itself bracketed by the target symbol on the Head-Up Display(HUD), the pilot can see some "blobs" behind the target designator and continue to prosecute his attack even though he will not be able to discriminate the blobs as oil tanks until within 700 yards. This type of simulation would be satisfactory for the evaluation of most aspects of state-of-the-art delivery systems and is, therefore, marginally acceptable.

1.3.3 Air-to-Air Visual Requirements

The field of view of the proposed Redifon system (48 x 32 degrees) is considered inadequate for use in free fight A/A simulation. Studies by McDonnell Douglas have shown that during a visual based A/A encounter, the target aircraft, when it is in the pilot's forward field of view, spends a significant percentage of its viewing time aligned with the vertical axis of the chase aircraft and between 40 and 60 degrees above the armament datum line as the pilot continuously rolls into and pulls toward the target aircraft. The 32 degree vertical FOV of the Redifon system, even if positioned so that the lower edge is at the datum, would still occlude such a significant portion of the requisite A/A visual environment that it is unacceptable for this type of simulation. This system could be used for certain "canned" scenarios or limited manuever A/A intercepts but full scale ACM, even if the subject's aircraft is pre-positioned at the targets "six" is not possible with this FOV limitation.

The update rate of 40/second should be fully acceptable. There are certain constraints on the interaction between relative image brightness, update rate, and target separation velocity which will have to be carefully evaluated, probably by system test, to insure the absence of perceptual aberrations. However, there is no reason to suspect that the system will be unsatisfactory in this respect.

The resolution of the Redifon system would appear to be totally inadequate for A/A simulation. The ability to judge the attitude of the target A/C relative to the chase plane is critical to the pilot's ability to anticipate target action and successfully achieve closure. This ability depends more upon the information content of the image (in terms of TV lines) as illustrated in Figure 5 than it does upon image size (subtended visual angle).

The number of lines required for a minimally acceptable orientation recognition percentage of 80 percent is 10 lines per aircraft height. This is equal to 50 minutes of subtended visual angle using the proposed system. Thus, an aircraft of the size of the F-18 would have to be within 200 yards range for 0.8 accurate determination of attitude. This is considered unacceptable for virtually all A/A applications. The only way to improve this recognition factor would appear to be through the use of a gimbaled TV projector with a field of view only large enough to encompass the target. This would increase the number of lines across the target aircraft and permit its position within the FOV to be controlled by the projection angle drive angle.

A summary of the proposed Redifon visual display system capabilities relative to the three primary missions (spin, A/G, and A/A) is shown in Table I.

1.4 DFS Communication and Data Recording Requirements

The conduct of large scale simulations requires the close coordination and integration of a number of different activities. These activities will be located as far apart as the CDC 6600 and the centrifuge itself. The safe and efficient conduct of simulation runs demands an adequate voice communications network and data recording system. The stations which must be coordinated during dynamic operations are:

(1) Project Officer Station
(2) Flight Director Station
(3) Biomedical Station
(4) Analog Centrifuge Control Station
(5) Experiment Control Station
(6) Central Computer System Station (CDC 6600)
(7) Subject Pilot Station (Gondola)
(8) Instrumentation Station

These stations and the equipment located at each are schematically illustrated in Figure 6. Other stations could be added as needed for specific simulations. All of these stations should be on a push-to-talk microphone and loud speaker/head set system. This system is mandatory for the confirmation of operational readiness during the experiment. It is also most helpful in allowing each station to monitor the status and progress of activities during centrifuge operations. The open net should have the capability for full recording of all communications. Voice activated recording should be considered to conserve tape.

In addition to voice, some transmission of TV would be helpful. There are at least two views available from Building 70: (1) a view of the chamber entrance and the centrifuge, and (2) a view of the subject from within the gondola. A third view of the cockpit instruments from behind the pilot's head may be implemented. This would enable the instruments to be monitored during simulator runs. These views are in addition to those essential to the simulation itself (such as terrain or target A/C presentation to the subject pilot) and are intended to facilitate the integration of centrifuge operations.

The smooth operation of the simulations, as well as their success in providing answers to the questions from which they originate, depends upon an adequate data acquisition, display, recording, and distribution system. In the DFS, data will be collected using digital, analog and visual monitoring techniques. Most of the information will be stored in digital format in the CDC 6600 which will enable the experiments to be replayed for detailed analysis. Replay is a necessary simulation mode as it would not be possible for the pilot to repeat exactly any behavior. The replay mode has an additional capability of distorting the real time to speed up, slow down or

TABLE I

MISSION CAPABILITIES OF THE VISUAL DISPLAY SYSTEM

	SPIN	A/G	A/A
FOV	SATISFACTORY	SATISFACTORY	MARGINAL
UP-DATE RATE	SATISFACTORY	SATISFACTORY	SATISFACTORY
RESOLUTION	SATSIFACTORY	MARGINAL	INADEQUATE

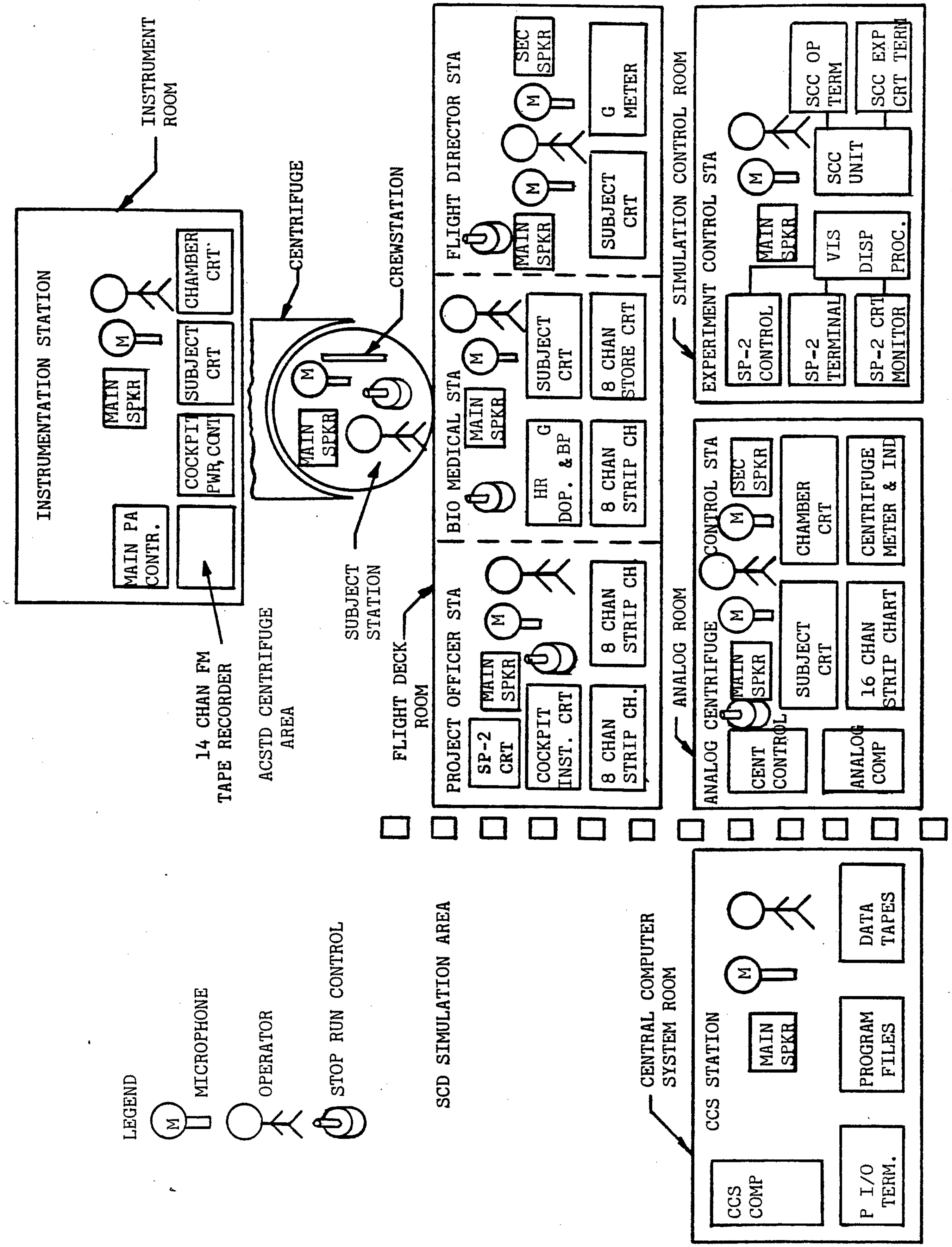


Figure 6. DFS OPERATIONAL STATIONS AND EQUIPMENT

freeze the run. This feature will be useful, for example, to slow a run to allow the pilot more time to assess his behavior or to report the many cues he utilizes.

Though the parameters which are recorded will vary as a function of the specific simulation purpose and procedure (see Section 1.7), some estimate can be made of the basic data distribution requirements. As a minimum the DFS should have the capability to record 64 channels of data with 100 preferred. Data recording may be in tape format or computer printout. At least 24 channels of real time graphic recording should be provided at the Project Officer's Station to permit immediate assessment of test run progress. In addition to the strip charts it is recommended that a number of CRTs be provided for monitoring of cockpit CRTs and the visual display system. Optional integrated parameter display's would be useful also, such as a programmable computer graphic terminal with the capability of presenting pre-planned boundary conditions and the integrated tracking of the DFS performance on 2 axes (for example AOA and airspeed).

Analog strip chart recorders will be used to record selected centrifuge control parameters and bio-medical data.

Medical parameters recorded and monitored should include:

1. Electrocardiograph (ECG)

2. Blood pressure, by means of a cuff.

3. Blood velocity using an ultrasound doppler sensor on the scalp.

4. Blood oxygenation by means of an ear oximeter.

5. Tracking task tolerance, monitoring the pilot's peripheral vision.

Video tape recorders (VTR) will be used to record visual data for both medical and procedural monitoring. A camera focused on the upper torso and face of the pilot throughout the data runs will reveal any signs of undue stress or harm and indicate the moment that the individual's g-tolerance has been reached.

In addition, to the real-time data recording, subjective data will be recorded from the questionnaire which is presented to the pilot subject after a run. Pilot observations should be noted and all reporting between the gondola and control stations over the intercommunication system must be recorded on audio tape. The time of the recording must be known in order to correlate the observations with the other data.

1.5 F-14 Spin Simulation Experiment Requirements

The Dynamic Flight Simulator is an important step between motion simulator investigations and flight tests. For the F-14 spin problem, the DFS may safely and economically evaluate departure avoidance/recovery maneuvers,

develop procedures for spin recovery and study pilot restraint systems under the stressful, incapacitating effects of the g-forces which are present during a fully developed spin.

In the development and evaluation of spin prevention maneuvers, the DFS is a critical link prior to the authorization of an expanded flight envelope for fleet pilots and aircraft. The four-phase research program being jointly conducted between the Navy, NASA and GAC, will provide data on an expanded flight envelope within which departure from aero-dynamic flight or spin entry can be avoided by the use of appropriate procedures. However these procedures will only be validated at that point for highly experienced test pilots flying a specially configured aircraft which is telemetering 200 channels of data monitored by twelve ground observers.

Before authorizing this expanded envelope for fleet pilots, it is essential that tests be conducted to develop assurance that standard fleet pilots can fly the envelope safely. This required assurance can be developed using the DFS in a two phase effort. The first phase would determine the effectiveness of the anti-departure procedures when used by highly experienced fleet pilots. After appropriate training runs, realistic scenarios would be used to require pilots to perform maneuvers to the limits of the expanded envelope and beyond into departure. When departure occurred, they would use the proposed procedures to attempt recovery. The aim of each run would be to test specific anti-departure procedures and the practicality of these procedures for fleet application. The DFS provides a safe, efficient vehicle for testing whether fleet pilots can effectively use these procedures without the enormous support sytems available to the test pilots at Edwards AFB.

The second phase of the program will address the important issue of determining training requirements to prepare standard fleet pilots to become proficient in the departure avoidance procedure. During this phase, pilots undergoing initial or transition readiness squadron training would be given special Operational Flight Trainer (OFT) training in the departure avoidance procedures. The effectiveness of this training would be evaluated by having the trainee fly the DFS using the scenarios and maneuvers of phase 1. At the completion of this 2 phased program, the expanded flight envelope could be authorized for fleet use with a reasonable assurance that further aircraft loss as a result of departure will be avoided.

While the F-14 departure avoidance/recovery program is the first program planned for the new DFS, it is representative of a wide variety of issues for which the DFS provides a safe, cost effective research vehicle. For example, the NASA Dryden team believes that with the proper procedures, the F-14 is recoverable from a fully developed flat spin. Since the DFS provides an almost perfect simulation of a flat spin, it would be prudent to test the procedures in the DFS prior to risking a pilot or the 1-X aircraft, even in the extremely well supported environment at Edwards AFB.

NADC can complement other research by investigating:

(1) The cues to departure, spin onset, spin recovery, and cues to recognition of different types of spin.

(2) The appropriate pilot response to the cues.

(3) The g-forces and the resultant incapacitation of the pilot.

(4) Restraint systems to reduce incapacitating effects.

1.5.1 Cues

A pilot is inundated with information from a number of sources. It is necessary to identify precisely the information which is acquired and that which is desired. Possible sources of cues for the pilot are:

1. Visual

    a. inside the cockpit, i.e. instrumentation
    b. outside the cockpit
    c. visual impairments, e.g. field-of-view, nystagmus, blurring.

2. Vestibular

3. Kinesthetic e.g. g-forces, buffeting

4. Auditory

1.5.1.1 Visual cues

Visual impairments are cues since these impairments also affect the pilot's ability to see other cues. G-forces change direction and magnitude so it is necessary to know which instrument and cue the pilot notes and when he notices these cues, also whether the information obtained by the pilot is sufficient for an effective response. In order to know what information the pilot is gathering during the simulator runs:

1. An interview/questionnaire may be conducted at the end of a test run.

2. The pilot may report through the intercommunication system from the gondola during the run.

3. Measurements may be taken to determine at which instruments the pilot is looking.

Visual impairments may be verbally reported, but the medical officer should be monitoring the pilot's peripheral vision also. He notes when there is a deficiency as it is an indication of the pilot having reached his g-tolerance threshold.

Results from a general investigation of the pilot's cues may indicate a need for new instruments or modifications which themselves should be evaluated. For example, a modification to be considered is an aural indication of engine stall, which would supplement the present caution lights

of low oil pressure. NASA has already developed such a system which may be tested in the DFS. An indication of any sudden or great increase in yaw rate is necessary possibly in the form of indicator flags as a three-stage warning system. Also the slip and turn indicator has been criticized for it's inadequate size during departure/spin.

The visual display system has the capability of presenting fog or cloud conditions (Ref. Section 2.3.3.2) providing a variable by which to assess the pilot's dependency on an out-the-window cue.

1.5.1.2 Vestibular cues

The main method to determine vestibular cues is by the pilot reporting during a centrifuge run. The vestibular experiences may be correlated with the time of occurrence during the run, the g forces, aerodynamic status and the pilot responses in terms of time and type or response. The analysis may indicate a significant correlation between vestibular cues and pilot performance and there may be inference that the performance is degraded by the vestibular experiences. To substantiate this, pilot reporting during the run will be supplemented by a detailed review of data during the post-run debriefing/interview.

1.5.1.3 Kinesthetic cues

The g forces may be felt and are perhaps a cue to the pilot when at a certain magnitude, or experienced from a particular direction. It would be worthwhile to determine at what time during the flight pattern and at what magnitude the g's become cues and when they are detrimental to performance.

Buffeting is also a cue which is related to the angle of attack of the aircraft. If the angle of attack is very high before the buffeting is noticed, other, earlier warnings should be devised and evaluated.

1.5.1.4 Auditory cues

There may be auditory cues experienced which should be determined so that there is a full assessment of pilot cues which may be evaluated in terms of pilot responses. An example of an auditory cue which could be implemented on the DFS would be a simulated aircraft engine sound.

1.5.2 Pilot Responses

The Navy/Grumman investigation is on the third phase of it's program which will define possible procedures for departure and spin avoidance and recovery. The procedures will be evaluated in a test flight, phase 4 of the program.

Using the unique capabilities of the NADC DFS, it may be possible to follow the pilot procedures proposed by GAC and evaluate their efficiency with the cues which will be identified. A comparison of GAC procedures and pilot responses during investigations of cues may lead to an alternative set of effective responses. To broaden the comparison, a set of procedures outlined by NATOPS for avoidance and recovery should be included. Manual wingsweep has been considered a possible aid to spin recovery (reference i) so it should be evaluated as a pilot response in a set of procedures.

1.5.3 Pilot Incapacitation

The effect of the g forces on the pilot would be evident during the investigation of cues and pilot responses but for clarity and a more controlled experiment, further centrifuge runs will be necessary. An open loop run, with the pilot instructed to respond at certain times, would determine under what g's he may reach certain controls and the force he can apply to the controls. Results from this investigation may indicate equipment modification. For example, the ejection lever may be re-positioned nearer the pilot.

During the simulation runs in the DFS, the pilot will be closely monitored by the medical officer. The medical officer will have the responsibility for the subject's health and the authority to terminate the centrifuge run as he sees fit. (Refer to Section 2.1.9.4) The subject will be monitored physiologically and visually to ensure that the incapacitation which will be experienced, is not excessive. (Refer to Section 1.4)

1.5.4 Restraint System

A program is scheduled to run on the centrifuge at NADC at the end of FY 81, which will evaluate at least 7 restraint systems. (ref. j)

1. MA-2 harness/negative g lap belt.
2. MA-2 harness/3" lap belt.
3. Alpha jet harness.
4. Martin-Baker Simplified Combined harness.
5. Blue Angels Special harness.
6. USAF PCU-15/P with HBU-10A belt.
7. Integrated leg restraint.

Control: MA-2 harness, unmodified

Both live subjects and dummies will be utilized, but the g-force will be limited to 3 g's.

A follow-on investigation should be conducted re-evaluating the most appropriate restraints identified from this program, under the higher g-forces which are experienced in departures and spins.

Inquiries into F-14 aircraft accidents, exposed a problem with the current restraint systems. (ref. a) If a pilot does not lock his harness prior to entering into a maneuver, incapacitation occurs earlier than it would otherwise as the pilot is malpositioned and is slowly forced forward with increasing g-force such that the inertial lock is rendered ineffectual. Because of this an evaluation of an Automatic Locking System of a restraint harness is needed.

1.5.5 Simulator Run Procedure

The pilot must be given a preflight physical by the medical officer and should be given a briefing packet which thoroughly explains the history of the experiment, features of the centrifuge, and the essence of the experiments including what is expected of the pilot.

Upon manning the simulator, a familiarization period must be provided during which the pilot is allowed to test the response of the aircraft while the centrifuge is inactive. Calibration of the total system however will be accomplished while the centrifuge is operational.

Training runs will precede data collection runs. It is also important for the pilot to be introduced to the dynamic environment, the displays, and the dynamic characteristics of the DFS. The pilot will be asked to follow certain ground rules, such as maintaining a good offensive position behind a target in an ACM simulation. For the trial run the target should follow simple maneuvers, such as steady turns, to allow the pilot to be familiar with the visual display, but not to acquire practice at more complex maneuvers programmed into the target display for the investigations.

An optimum simulation would involve tracking a target which is programmed to perform idealised Air Combat Maneuvers (ACMs) at high AOA and low airspeed so that the pilot tracking it will be provoked into departure from steady flight as he would be in a simulated fleet configured aircraft. The target tracking scenario is a highly desirable capability in the DFS and should be given priority in the future capability development program. With this feature, runs would be closed loop, but a replay mode will allow for subsequent open loop runs. The replay feature should be flexible to allow for a pilot to intervene at a specified point in the test run, completing the run in a closed loop mode.

The maximum g-force a pilot may tolerate in a g-suit is approximately 10 gs. The centrifuge will be halted if the pilot appears to be nearing his tolerance threshold.

After a run or series of runs, the pilot should have a post-flight medical exam and a debriefing which may entail a questionnaire and a structured interview.

1.5.6 DFS Operating Modes

The DFS will have various modes of operation. These modes are selected by the experiement control operator. As a minimum the following modes will be available:

(1) Start Up

The DFS provides a start up mode. Under this mode, the experiment control operator may select the aircraft model which is to be tested, and initiate the experiment.

(2) Test

The DFS provides a test mode. While in this mode the centrifuge is motivated and visual displays are activated according to pre-determined flight controls. This mode shall be used to guage the validity of the components of the DFS.

(3) Coast

The DFS provides a coast mode. While in this mode, the operator establishes initial conditions for the subsequent experiment, or allows the conditions to default to values which are determined beforehand.

(4) Run

The DFS provides a run mode. While in this mode, the DFS drives the centrifuge motion in such a way as to simulate the effect of an aircraft under control of the pilot in the cockpit.

(5) Termination

The DFS provides a termination mode. While in this mode, the DFS provides an orderly termination of the DFS simulation.

1.6 F-14 SPIN SIMULATION EXPERIMENTAL CONTROLS

1.6.1 Fidelity

High fidelity of the simulator is very desirable for greater pilot acceptance and more accurate and valid results. The DFS will have a realistic F-14 cockpit with all relevant instruments active. (Refer to Section 2.3.3.7) Three highly experienced F-14 pilots provided final decisions in the selection of the active instruments.

Fidelity is enhanced with the implementation of a VDI and HSD. While the present visual display system is documented as unsatisfactory for air-to-air combat (Refer to Section 1.3), it could provide simulation for the tracking task which has been suggested in 1.5.5.

The motion profile must include buffeting as a function of AOA and any pedal shaking or motions which may occur in actual flight. Absolute fidelity should be attempted with the aircraft response to pilot inputs including motion, visual, and instrument updates.

The aerodynamic modeling of the simulator must be capable of handling the higher gross weight and stores configurations typical of fleet aircraft. This is needed to investigate the apparent statistical correlation between departure-related aircraft losses and heavier gross weight configurations. The problem of aircraft loading has been studied at NATC in flight tests and is still being considered by GAC.

The Automatic Flight Control System (AFCS), Stability Augmentation System (SAS) and the Aileron-Rudder Interconnect (ARI) are systems which must be included in the simulator programming. As departure from controlled flight occurs, the pilot may respond by deactivating the systems. Therefore, their variables must be included in the aerodynamic package.

1.6.2 Target Programming

A convenient approach to programming the target in an ACM Simulation follows a method by Gilbert and Nguyen (Ref. k). The target aircraft must be programmed to have the same thrust and performance characteristics as the simulator but with idealized high AOA lateral/directional stability and control characteristics. The simulator is "flown" through simple tasks for the trial runs and a set of ACM tasks. The resulting motions are recorded on magnetic tape and played back as the target aircraft. The simulator is then used to track the target while programmed as a fleet configured aircraft.

It is necessary to have different pilots for programming the target and undertaking the experiment runs. If a pilot is too familiar with the tracking tasks, he may not follow the ground rules but rather outplay the target, possibly avoiding departures and spin conditions which are desirable for the study.

1.6.3 Pilots

The DFS project office should be staffed with a senior, experienced F-14 pilot for ensuring that software and hardware development are realistic. Either an active duty pilot, or recently separated pilot can fill this role. A highly experienced pilot would be required to program an ACM target display. Test pilots from NATC, GAC or NASA Dryden should be used for final evaluation of the simulation prior to experimental data collection. Subjects for the data collection runs should initially be highly experienced fleet pilots. Later experiments will be conducted using low to moderately experienced "standard" fleet pilots.

1.6.4 Life Support Systems

A suitable aircraft ejection seat must be installed. The pilot should wear a g-suit and be equipped with a standard pressure breathing air system and a face mask with built-in microphone.

An air conditioning system should be installed to cool the gondola interior. A standard restraint system should be used except when evaluating a new design.

1.6.5 Control Stations

The stations which are essential and the communication networks required have been outlined in Section 1.4. Section 2.1.9 details the responsibilities of the 8 main controllers of the DFS operation, methods of terminating a run and emergency procedures.

Data channels between stations have been outlined (Section 1.4) but the display of the data at each station, the recording and distributing of the data and personnel requirements are yet to be defined. This will be done when the detailed F-14 Spin experiment requirements are developed.

1.7 F-14 SPIN SIMULATION DATA COLLECTION REQUIREMENTS

The main intent of the data collection is to have the ability to reconstruct significant elements of a data run on paper. Essentially it is necessary to know at certain periods of time:

1. Flight instrument data
2. Aerodynamic data - basic flight parameters
   - control surface positions, which includes ailerons, rudder, speedbrakes, flaps, spoilers and wingsweep
   - aircraft responses - other than those included in flight instrument readouts.
3. Pilot responses/inputs and the force exerted on the controls.
4. Environmental data - g-forces, temperature, noise, vibration.

This data would be sufficient for most of the investigations of g-forces and cues. Other experiments may require additional kinds of data. For example, in the evaluation of restraint system, the force required to lock the harness and the time it was locked must be recorded, as well as the g-force at that moment.

The actual parameters which will be monitored during the F-14 Spin Simulation are listed in Table II. In addition to these parameters, biomedical data, as specified in section 1.4 will be monitored to ensure the safety of the subject pilot.

Table II. Data Collection Parameters

1. Basic Flight Parameters

Altitude	h
Airspeed/Mach	As
Roll rate	p
Dynamic pressure	Q
Pitch acceleration	$\dot{q}$
Pitch rate	q
Yaw rate	r
Angle of attack	α
Total angular rate	Ω
Engine trust levels	T_L, T_R
Side slip angle	β

2. Control Surface Positions

Manually selected sweep angle	Λ MAN
Wing sweep angle	Λ MAN
Output of wing sweep schedule	Λ AUT
Differential tail deflection	δ aLIM (Limits Applied)
Stabilator deflection	δ eLIM "
Rudder deflection	δ rLIM "
Spoiler deflection	δ spLIM "
Speed brake deflection	δ Sb

3. Cockpit Instruments

VDI
HSD
HUD
Barometric Altimeter
Airspeed
Angle of Attack
Wing Sweep Indicator
Accelerometer
Engine: RPM, Turbine Inlet Temperature, Fuel Flow
Turn and Slip
Rudder Turn Indicator
Flaps, Slats and Speed Brake Indicators
Spoilers and Rudder Indication
Master Caution
Position of HUD Declutter Switch
Caution Panel
Harness Locked

Page 1 of 2

4. Pilot Response Data

Rudder pedal deflection	δ DIR
Lateral stick deflection	δ LAT
Longitudinal stick deflection	δ LONG
Total force applied to lateral stick	F LAT
Total force applied to longitudinal stick	F LONG
Total force applied to rudder pedals	F PED
Directional SAS switch position	δ SASWD
Longitudinal SAS switch position	δ SASWL
Lateral SAS switch position	δ SASWLT
Directional trim switch position	δ TRD
Longitudinal trim switch position	δ TRL
Lateral trim switch position	δ TRLT
Left engine throttle position	δ THl
Right engine throttle position	δ THr
Position of manual sweep override switch	δ_Λ MAN
Position of speed brake switch	
Position of airstart switch	
Position of HUD declutter switch	
Emergency jettison button activated	
Position of landing gear	
Force applied to ejection lever	

5. Environmental Data

G-force
Temperature of cockpit
Noise level
Vibration
Buffeting of cockpit

Page 2 of 2

1.8 F-14 SPIN SIMULATION DATA REDUCTION REQUIREMENTS

A general time history in the form of a strip chart is useful for presenting main variables such as pilot inputs, AOA, sideslip, airspeed, roll, pitch, and yaw angles, rates, and g-forces. The charts would give a gross and quick indication of how the run is going.

Off line data reduction has yet to be defined. It should be possible to command an output which would tabulate, for example, the length of time it took the pilot to respond to a cue under one set of conditions and the length of time under another set of conditions. Likewise, any appropriate statistics, such as analysis of variance or correlations could be generated.

The data reduction may be specified as the experimental runs are more closely defined. A presentation of data should be as clear as possible in tabular or graphic form.

See Section 1.4 for discussion of programmable computer graphic terminals as data display and reduction devices.

2.0 Dynamic Flight Simulator System Description

2.1 Centrifuge Motion System

The NAVAIRDEVCEN centrifuge (Figure 1) consists of a tubular steel arm, 50 feet long, which is rotated in a horizontal plane about the axis of a vertically mounted 4,000 hp direct-current motor. The test subject is enclosed in a spherical gondola, 10 feet in diameter, located at the end of the arm. The gondola is attached to the end of the arm by means of a two-gimbal system which permits complete rotational freedom of the gondola. This gimbal system consists of an outer gimbal which rotates about a horizontal axis perpendicular to the centrifuge arm, and an inner gimbal which rotates about an axis in the plane of the outer gimbal ring and perpendicular to the axis of the outer gimbal. Each gimbal is driven by an electro-hydraulic system located on the arm near its hub. Access to the gondola is provided by means of a retractable platform located in the wall of the 124 feet diameter centrifuge chamber.

The control station including associated computer equipment is located immediately outside the centrifuge chamber wall and on the chamber floor level. The rotating machinery and associated equipment with the exception of the main drive motor are located in a remote power house connected to the main drive motor area by means of a tunnel.

The following centrifuge description and specifications have been exerpted from Reference 1.

2.1.1 Centrifuge Arm

a. Physical Description

1.	Length of arm from axis to subject station	50 feet
2.	Weight of total rotating structure including main motor gondola, and payload	297,000 lb.
3.	Moment of total rotating structure	30,440,000 lb.ft^2
4.	Approximate percentage correction of overturning moment by counterweight	70%
5.	Resonant frequency	2.8 hz

b. Main Centrifuge Drive Motor

1.	Nominal rating	4,000 hp
2.	Maximum hp available	16,000 hp
3.	Maximum torque	1,700,000 ft.lb.
4.	Maximum speed	48.5 rpm
5.	Maximum armature voltage	600 volts
6.	Maximum armature current	20,000 amps.

c. Overall performance of centrifuge arm with 1,000 lb. payload

1.	Maximum g level	40 g
2.	Average rate of change of G above 1.8G	10 g/sec.
3.	Maximum angular acceleration	1.8 rad/sec^2
4.	Maximum tangential acceleration in gondola	2.8 g
5.	First order transfer function model	$\frac{e^{-0.20s}}{0.481s + 1.0}$

2.1.2 Outer Gimbal Axis - Normally Controls Subject's Roll Attitude

a. Physical Description

1.	Weight of total rotating structure about gimbal axis including gondola and payload	6,000 lb.
2.	Moment of total rotating structure about gimbal axis including gondola, payload, and motor end of hydraulic transmission	134,300 lb.ft^2
3.	Outer gimbal ring surrounds sperical gondola and is octagonal in shape	

b. Outer Gimbal Drive System

1.	Nominal rating of drive motor	75 hp
2.	Maximum output torque of hydraulic transmission	1,000 ft.lb.
3.	Overall gear ratio between output end of hydraulic transmission and outer gimbal	30 to 1

c. Overall Performance of Outer Gimbal Axis

1.	Maximum angular acceleration	6.5 rad/sec^2
2.	Maximum angular velocity	30 rpm
3.	Continuous rotational capability in either position or rate control	
4.	First order transfer function model	$\frac{e^{-0.14s}}{0.279s + 1.0}$

2.1.3 Inner Gimbal Axis - Normally Controls Subject's Pitch Attitude

a. Physical Description

1.	Weight of total rotating structure about gimbal axis including gondola and payload	2,934 lb
2.	Moment of total rotating structure about gimbal axis including gondola, payload, and motor end of hydraulic transmission	53,100 lb.ft^2

b. Inner Gimbal Drive System

1.	Nominal rating of drive motor	40 hp
2.	Maximum output torque of hydraulic transmission	700 ft.lb.
3.	Overall gear ratio between output end of hydraulic transmission and inner gimbal axis	27 to 1

c. Overall Performance of Inner Gimbal Axis

1.	Maximum angular acceleration	9.5 rad/sec^2
2.	Maximum angular velocity	30 rpm
3.	Continuous rotational capability in either position or rate control	
4.	First order transfer function model	$\frac{e^{-0.12s}}{0.280s + 1.0}$

2.1.4 Centrifuge Gondola

a. General Description

1. Spherical in shape with O.D. of 10' 4".
2. Upper and lower hemispherical caps which are attached to center structural segment are removable for easy insertion of gondola inserts via overhead crane on monorail.
3. Center structural segment is a 10 ft. diameter cylinder, 31.24" high and 6" thick. Special attachment fittings are symetrically located on the inside wall of this segment to enable it to structurally support the entire gondola insert.
4. A circular gondola door is located in the upper hemispherical cap and is 38" in diameter.
5. Gondola is capable of supporting a 1,000 lb. payload at 40 g.

b. Vacuum Capability

1. Normal rating-vacuum equivalent at 100,000 ft. altitude
2. Externally controlled through two 2" rotary joints.
3. Special hemispherical caps are provided which have been tested to 29.3 psi differential pressure and are essentially reinforced monocoque structure.

2.1.5 Centrifuge Slip Rings

a. Gondola slip ring complement. (Refer to Table III)

Table III. Gondola Slip Ring Complement Description

Section	Quantity	Current Rating	Volts AC	Shielding
Physiological	15	1 amp	250	Individual
Instrument and Control	48	5 amp	250	Pairs
Instrument and Control	26	1 amp	250	Pairs
Power	16	15 amp (Gondola)	230	---
		35 amp (Hub)		
Coaxial	19	75 ohm	250	Individual
		30 mc		
TOTAL	124			

b. Centrifuge hub axis slip ring complement is the same as the gondola with the exception of 20 additional instrument and control rings rated at 5 amps which serve the arm only.

c. Increased slip ring requirements can be satisfied by utilizing multiplexing techniques.

d. The physiological circuits are designed for low noise (1 microvolt) and use rhodium-plated copper rings with six microinch finish, and gold-plated wire brushes.

2.1.6 Centrifuge Rotary Joints

a. Total of six rotary joints available to convey fluids into and out of the gondola - three on each side.

Gondola Rotary Joint Complement

Service	Tube Size (Nominal)	Design Pressure (Maximum)
Air Conditioning/Vacuum	2 inch	15 psi (external)
Hydraulic O.P. (Petroleum Base)	3/4 inch	3000 psi
Compressed Air	1/2 inch	100 psi

b. Two independent rotary joints (nominal 3-inch tube size for vacuum or conditioned air and a 1/2 inch rotary joint for compressed air are available at the centrifuge hub axis.

c. The rotary joints are designed to permit adjustment of the seals without removing the rotary joint assemblies from the trunnions.

2.1.7 Centrifuge Control

a. Special features include advanced capabilities in:

1. System Performance - Ease of adjustments to permit performance optimization at all axes.
2. Safety - Safe operation with redundant interlocks on each sub-subsystem which essentially makes the entire operation both machine-proof and man-proof.
3. Monitoring - Centrifuge operator has immediate read-out of all parameters including television coverage of centrifuge and subject.
4. Mode-Control - Individual control is available for each. (Refer to Section 1.5.6)

2.1.8 Centrifuge Dynamics

The centrifuge g vector (G) is the normalized reaction to the acceleration existing at the center of the centrifuge gondola. It is produced by both gravity and the centrifuge arm rotation and is oriented in the subject pilot frame using the two gimbal positions. The centrifuge produced components of the centrifuge g vector are; tangential g (GT), due to the arm angular acceleration ($\dot{w}$); and the radial g (GR), due to the arm angular velocity (w). These two components and the component of gravity compose the three orthogonal components of the centrifuge g vector in the centrifuge arm frame.

Several features of the centrifuge g creation are seen in a plot of arm angular velocity vs. arm angular acceleration. This phase plane plot of w vs $\dot{w}$ with contours of constant total g is shown in Figure 7.

In this plot particular values of g magnitude are represented as contours. The origin is the minimum g contour having a value of one g. Each point on the plane represents the centrifuge state and has an associated g magntidue. The directed contours indicate the state movement required to retain constant g. The line created by the locus of zero angular acceleration is the set of points where constant g can be maintained with a constant centrifuge state. First and second order linear dynamic models of the arm servo system can also be graphically represented in the phase plane making it an important tool for understanding the centrifuge.

When using the centrifuge as a simulator it is necessary to map the zero to two g region of the aircraft into the centrifuge one to two g region. This is done to allow reduced centrifuge g when the aircraft experiences less than one g and means that one g of the aircraft corresponds to an operating g value of the centrifuge called a plateau. The plateau decreases the angular rates and angular acclerations and increases the ability of the centrifuge to produce high g onset rates.

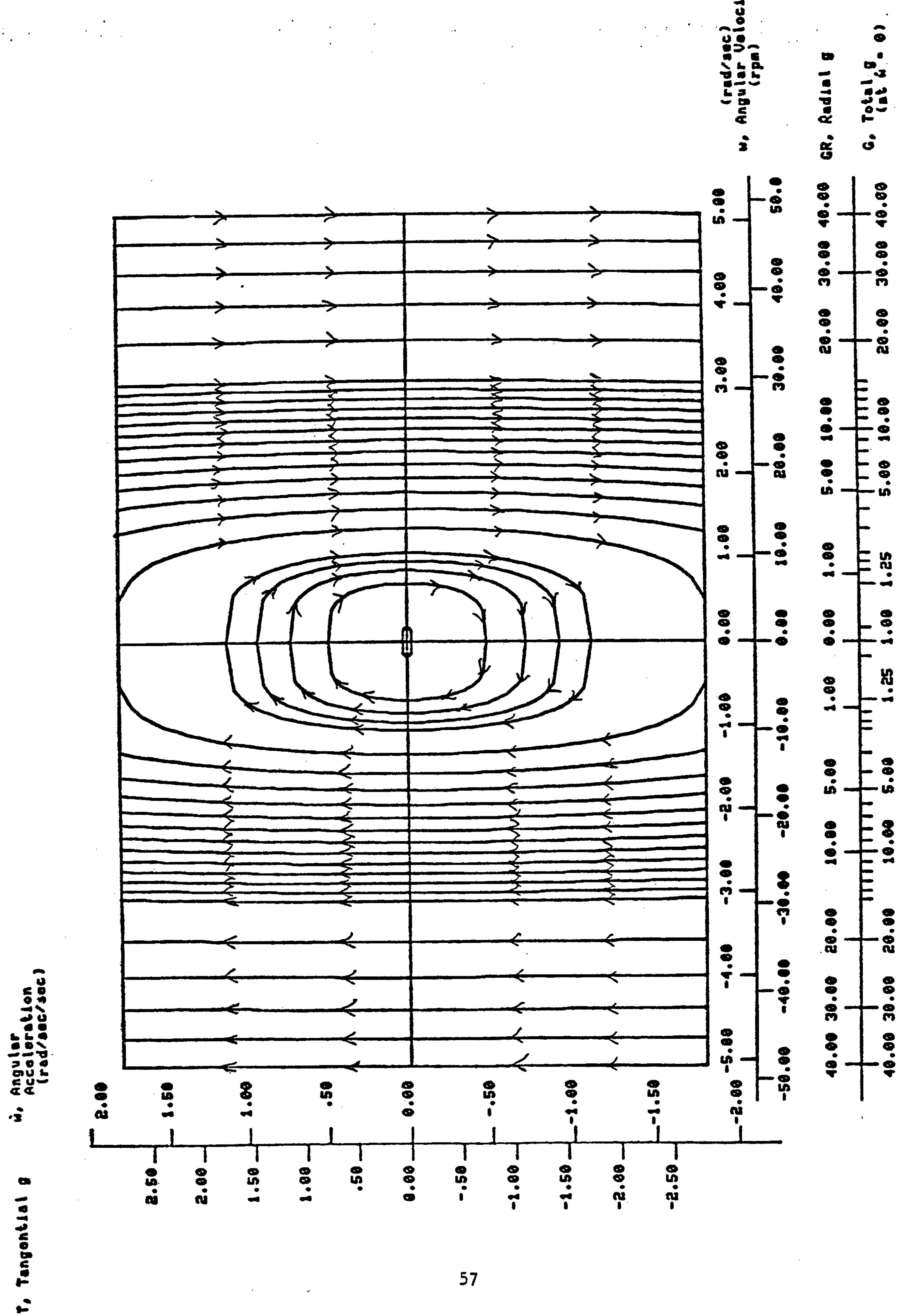


Figure 7. NADC Centrifuge Arm Phase Plane with g Contours

2.1.9 Centrifuge Operation

2.1.9.1 Responsibility

All persons involved in the dynamic operation of the centrifuge will exercise prudence in carrying out all phases of this program. Common sense should be used in addition to the rules contained herein, to insure a safe program. Procedures and project limits established herein will not be varied or exceeded in any way without the specific approval of the ACSTD Director. Any abnormality that might in any way affect the safety of this program shall be referred to the ACSTD Director for his decision before proceeding.

(1) Project Officer

The Project Officer is the program sponsor or the sponsor's authorized representative. His primary responsibility is to provide a working interface between the program operations team and the desired technical objectives of the test program. He will be present during all formal data acquisition phases of centrifuge operations, both static and dynamic conditions. His presence at other times, such as during the test and check-out operations, is at the discretion of the Project Officer himself or by the request of the centrifuge operations team. He may assume certain specified functional duties not directly related to the safety of centrifuge operations. Such a duty would be an "on-line" performance data monitor. The Project Officer will have access into the communications net only as outlined in Section 1.4. The Project Officer will conduct all subject briefings and debriefing sessions as far as they pertain to the test objectives of the program. Operational procedures and safety briefings will be conducted by the Flight Director or his representative. Because the test objectives are the prime purpose of all programs, the Project Officer can request that the test be stopped or aborted at such time as the test objectives have not been met or cannot be met due to failures of equipment or other unforeseen situation.

(2) Flight Director

The Flight Director is responsible for the orderly and safe conduct of the operational phase of the centrifuge program. He will function as the central coordinating station during all manned dynamic operations. All communications must be conducted through the Flight Director station unless otherwise authorized by the Flight Director. The Flight Director will insure the operational readiness of the gondola and cockpit installation, its occupant and all other operational aspects required to secure the centrifuge for dynamic operation. Only after the Flight Director has reported all secured for the Analog Centrifuge Control Operator and ascertained a "GO" operational status from all other stations and the pilot, will a GO status be assumed. The Flight Director shall conduct all tests in strict accordance with the detailed procedure set forth in the test

plan so far as is possible. He will establish that the detailed procedure is workable during check-runs and drills. Final modifications to the detailed countdown procedures shall be made during the check run period. During the conduct of a test the Flight Director may find it necessary to alter the countdown procedure to conserve time or test continuity. He shall have the authority so long as the test objectives are not compromised and safety is not jeopardized.

(3) Medical Officer

The Medical Officer is responsible for the medical safety and well-being of the subjects. He will insure that he and all the members of his team are familiar with the purposes and procedures of this project, and with the operation of all emergency medical equipment and procedures, as well as the ready status of such equipment prior to commencement of dynamic-centrifuge operation with a human subject. During the manned check-out phase of operations emergency drills will be directed by the Medical Officer. The Medical Officer shall ascertain the physical and mental readiness of the subjects by review of health records and physical examination. The extent of the physical examination, e.g., whether or not a ECG will be required, will be left to the discretion of the Medical Officer. During the centrifuge run, the Medical Officer shall monitor the well being of the subject. He will have available to him a continuous recording of the subject's ECG and one performance parameter. Should he deem it necessary, he will be able to converse with the subject during a run and/or view the subject via the television installation. Any time the Medical Officer considers a medical emergency to have occurred, he is authorized to to initiate a normal stop immediately and will announce the medical emergency over the loud speaker. In the event of a medical emergency, the Medical Officer will direct all operations. Following all centrifuge runs all subjects will be examined by the Medical Officer as he deems necessary.

(4) Analog Centrifuge Control Operator

The Analog Centrifuge Control Operator is responsible for the proper and safe operation of the mechanical and electrical aspects of the computer-centrifuge complex.

(5) Experiment Control Operator

The Experiment Control Operator is responsible for ensuring that the proper simulation environment is maintained on the Simulation Control Computer (SCC) throughout the simulation experiment. Responsibilities of the experiment control operator include but are not limited to the following items:

- initialization of the SDC DFS software

- initialization of all SCC peripherals including the fiber optic link to the CCS

- making experiment control operator programmed inputs consistent with the DFS experiment requirements and centrifuge operation.

- execute and verify manned and unmanned testing of the DFS software

- proper termination of the DFS experiment.

The experiment control monitor shall have the responsibility to stop the centrifuge motion with a normal stop if unsafe condition of an aspect of the DFS is deemed by him to be present or imminent.

(6) CCS Operator (CDC 6600)

The CCS operator has the responsibility to ensure that the CCS is in the proper condition for the dynamic flight simulation experiment to proceed. This includes all aspects of the CCS involvement with the DFS, among them being scheduling, operation, termination, and data collection/analysis.

(7) Subject Pilot

The Subject Pilot's responsibilities are dependent on the requirements of the experiment. He is to follow the orders of the Flight Director and maintain a constant dialogue with the project team by reporting all sensations experienced during the course of the experiment.

(8) Instrumentation Operator

The Instrumentation Operator has the responsibility to ensure the hardware at the instrumentation station is fully operational. This includes a 14 channel instrumentation tape recorder, the main public address system, and all power requirements in the centrifuge gondola. In addition this operator shall secure power to the centrifuge gondola in the event of an emergency.

2.1.9.2 Required Check-Run

During dynamic operation, the arm radial acceleration is electronically limited at approximately 0.50 greater than the maximum anticipated.. A check (unmanned dynamic) run will be made each day prior to the commencement of the manned runs, and may be made at such other times as the Flight Director or the Analog Centrifuge Control Operator may require. The purpose of this run is to verify the correct functioning of the equipment. During this run, the gondola will be unoccupied.

2.1.9.3 Run Termination Methods

There are three different methods for terminating a dynamic run. Their nomenclature and the location of the controls for implementing them are listed below.

a. Normal Stop

1. Analog Centrifuge Control Operator's Station
2. Automatically initiated if pre-set limits of "g" or gimbal error are exceeded.
3. Automatically initiated if failure occurs in computer (overload), loss of power, mechanical limit switches or gimbal resolvers activated.
4. Initiated by Simulation Control Computer if errors are detected or if on final computer-controlled stop.

Normal stop disconnects the computer from the crewstation, automatically decelerates the centrifuge, holds the gimbals until arm decelerates to 3 rpm and then erects them (unless previously elected to continue holding) and brings the arm to rest at the loading platform. If gondola positioning is required after the initiation of a normal stop (or CC stop), the stopping sequence must be completed first. However, if it has previously been elected to hold the gimbal, this may be changed to erect the gimbal at anytime during the stopping sequence.

b. C.C. Stop (Computer Controlled Stop)

Buttons for initiating C.C. Stop are located at:

1. Flight Director Station
2. Biomedical Station
3. Analog Centrifuge Control Station
4. Experiment Control Station
5. Subject Pilot Station

The C.C. Stop used with the DFS will cause the centrifuge to return to the plateau g level corresponding to one g in the aircraft as decribed in section 2.1.8. It will do this in a controlled coordinated manner in four seconds or less.

c. Emergency Stop

This mode disconnects all power to centrifuge drive motor and applies dynamic braking. Gimbals will freeze at position existing at time of emergency stop activation and the arm will stop at a random position.

1. Analog Centrifuge Control Operator's Station
2. Automatically initiated if the following pre-set limits are exceeded and generator difference current, arm error, or the G is in excess of radial G specified in pre-test limits.
3. Automatically initiated if loss of power occurs in centrifuge console or powerhouse.

d. Torque Limiter Initiated Stopping Sequence

The drive shafts controlling the inner (B) gimbal on the centrifuge are fitted with two torque limiters. The function, as the name implies, is to limit the maximum torque that can be applied to the inner gimbal drive mechanism in order to protect and preserve the mechanical integrity of the drive system. In the event there is cause for the torque limiters to operate (exceeding the pre-set torque value) the effect would be to allow the inner gimbal to slip in one or more steps and hold. The operation of the torque limiters will automatically initiate an immediate centrifuge NORMAL STOP sequence. The Normal Stop will freeze the gimbals (A and B) in position, decelerate the centrifuge arm and during the final 90 degrees of rotation the gimbals are erected to a zero-zero position (or as preselected).

NOTE: If the NORMAL STOP has been initiated by the torque limiter, the inner gimbal will be OFFSET from its zero-zero position an amount equal to the limited slippage (10 degree increments at the gondola) allowed by the operation of the torque limiters.

CAUTION: Ingress and eqress of the gondola may become difficult or hazardous, depending on the direction and amount of this OFFSET.

It shall be standard procedure for the Flight Director to control the boarding of the gondola during all torque limiter initiated NORMAL STOPS. If the situation is not critical the Flight Director may elect to have the inner gimbal repositioned to its normal zero-zero position either manually or under control of the Analog Centrifuge Control Operator before any boarding attempts are made.

It shall also be standard procedure to secure from continued operations after a torque limiter/Normal Stop until the torque limiters have been reset and the gondola is reported to be realigned to its zero-zero position and operating normally.

2.1.9.4 Run Termination Responsibility

Runs should be stopped by authorized operational personnel whenever they believe conditions warrant it. The personnel authorized to initiate run termination are listed below. Whoever terminates the run should identify his atation and state the reason over the intercom. The following are cases wherein the run should be stopped as indicated:

a. By the Medical Officer.

1. Physiological and/or support equipment malfunction.
2. Any time at which the Medical Officer suspects subject unconsciousness as indicated by TV monitor or physiological measurements during acceleration or when there is no response from the subject on the intercom to questions as to the subject's condition.
3. The appearance of a period of moderately unusual pre and/or post ECG complexes.
4. Period of blackout in excess of three seconds.

b. By the Analog Centifuge Control Operator (using stop dictated by circumstances).

1. End of run.
2. Equipment malfunction.
3. An arm radial acceleration exceeding the g limit.
4. Lighting of the panel "Coast Light" indicating that the arm power circuit breaker has opened. This feature is automatic with manual back-up.

c. By the Flight Director.

1. An indication of equipment malfunction.
2. Any abnormal situation which makes continued dynamic operation unsafe.

d. By the Subject Pilot.

1. Personal discomfort or distress.

2.1.9.5 Emergency Procedures

As soon as the centrifuge begins to stop, for any reason, the Pilot shall state his medical condition. If there is no reply or if there is a statement of "Medical Emergency", the Medical Officer will request the Analog Centrifuge Control Operator to bring the gondola to the platform and indicate the desired position of the subject.

a. If the Analog Centrifuge Control Operator feels confident as to the operation of the motion control system, he will bring the gondola to the platform and position the pilot in the upright position unless otherwise directed by the Medical Officer. The Medical Officer may then enter the gondola and administer or direct aid to the subject. The Flight Director will remain at his station to assist in other emergency support activity, and the Medical Corpsman or others as designated by Medical Officer shall prepare the cardiac pacemaker and other medical emergency equipment for use, and assist the Medical Officer as directed.

b. If the gondola is not at the platform, and if the Analog Centrifuge Control Operator questions the proper operation of the motion control system - for example, following the opening of the arm power circuit breaker - he will sound the siren. The installation mechanics, other pilots, and support personnel shall enter the chamber. If the pilot is not in the required position, he will be placed in that position by the manual rotation of the gimbals followed by manual rotation of the arm to place the gondola at the loading platform. The Medical Officer and the Flight Director, will assume the responsibilities as outlined in this section. Platform operational personnel as directed should stand by to provide assistance as may be required. All other personnel should leave the platform. Excessive noise or congregation on the platform should be avoided.

c. All hands may enter the centrifuge chamber with caution any time after siren sounds.

2.1.9.6 Communications Procedures

Microphone and speakers or headsets are provided at all operating stations.

a. Stations on the communications net include the following.

1. Flight deck (Bldg 70)
   (a) Flight Director
   (b) Medical Officer
   (c) Project Officer
2. Centrifuge (Bldg 70)
   (a) Pilot (subject)
3. Operations/Computer room (Bldg 70)
   (a) Analog Centrifuge Control Operator
   (b) Experiment Control Operator
   (c) Instrumentation Station
4. Central Computer System Operator (Bldg 1)

b. Communications extraneous to the prosecution of the runs will be carried on by telephone or other means. Intercom communications will be subjected to the following restrictions.

1. In general, whenever the pilot is in the gondola or the centrifuge is in motion, use of the intercom will be kept to a minimum.

2. During dynamic runs, the Flight Director's, Medical Officer's, and Corpsman Stations will be manned.

3. All stations shall identify whom they are calling and who is making the call, using position rather than personal name; e.g., "Pilot from Medical Officer", etc.

4. Whenever the pilot is speaking, all other stations should refrain from speaking and should listen attentively.

2.2 DYNAMIC FLIGHT SIMULATOR FLIGHT DYNAMIC MODELING

2.2.1 Equations of Motion

2.2.1.1 Description of Equations

The need for the proposed F-14 Spin Simulation to represent the extreme high angle of attack flight regime is what distinguishes it from other simulations. Therefore the requirements of this feature are the driving factors in specifying the equations of motion. Several considerations peculiar to this type of simulation may be listed as:

1. Nonlinearity of data

2. Uncertainty about form of data

3. Importance of various asymmetries

4. Large angle motions

Just how each of these factors impacts the form of the equations of motion will be pointed out in this section.

The aerodynamic force and moment data typically changes very rapidly and often unexpectedly with changes in the orientation of the free stream velocity vector. Furthermore, there are no guarantees that trim is possible at all flight conditions of interest.

The aircraft may undergo such extremely violent excursions that any state of equilibrium may be simply a very brief transient state. Under these conditions the conventional stability derivatives have little meaning. That is, the concept of aircraft motions consisting of small perturbations from an equilibrium condition is not applicable. For this reason the usual linearization of the rigid body dynamic equations, whether for analysis or simulation, is inappropriate. The full nonlinear rigid body dynamic equations must be used.

These equations arise from the six degree of freedom equations of Newtonian dynamics,

$$\vec{F} = \frac{d}{dt} m\vec{V} \qquad \vec{T} = \frac{d}{dt} I_n \vec{\Omega}$$

which define force and moment as the first derivative of linear and angular momentum, respectively. These equations are defined for inertial (nonaccelerating, nonrotating) reference frames.

If we wish to write the force and moment equations in a reference frame that may be rotating, we must remember that differentiation of any vector V in such a system requires an additional term,

$$\frac{d\vec{V}}{dt} = \dot{\vec{V}} + \vec{\omega}_{co\text{-}ord} \times \overline{V}$$

to represent the inertial quantity.

The assumption that mass and inertia are approximately constant for the time required to pass through the equations of motion once yields,

$$\vec{F} = m\vec{a}^* \qquad \vec{T} = I_\Omega \dot{\vec{\Omega}} + (\vec{\Omega} \times I_\Omega \vec{\Omega})$$

Making this assumption essentially selects body axes as the reference frame for all forces and moments because it is the only reference frame in which inertias are constant with time. To avoid unnecessary axes conversions, it will be assumed that all aerodynamic data will be in body axes.

2.2.1.2 Equation Summary

NADC report 80220-60 (Reference m) provides a detailed description of the aircraft equations of motion derived from these classical rigid body dynamic equations. A summary of those equations are provided in Figure 8.

The resultant equations do not require mass symmetry but do assume constant cg location and inertias for the period of the test run. Modeling fuel slosh or the relatively long term effects of fuel consumption requires introducing time dependence into weights, inertias, and cg locations. Flexibility is not accounted for since no reliable high angle of attack or spin mode data is available which accounts for flexibility. Forthcoming parameter identification data is the most likely future source of such data.

The equations are written in terms of body axis acceleration components which may be put through any coordinate transformation and integrated using the linear control system representations described in 2.2.2 to obtain any desired rate or position information.

The applied forces and moments arise from aerodynamics, propulsion, and gravitation. All dynamic inertial coupling and engine shaft gyroscopic moments are also represented. All engine parameters, propulsive forces and moments are accounted for separately allowing investigation of failure states.' Engine dynamics are modeled as control system components.

Aerodynamic forces and moments are not expanded into explicit Taylor's series expansions. Such a procedure implies linearity of input data. Rather, each coefficient is represented as the sum of a number of components extracted from a like number of tables. This allows the use of any combination of linear or non-linear data appropriate to the available data base.

Linear Degrees of Freedom:

$$a_x = g\,(F_x/W - \sin\theta)$$

$$a_y = g\,(F_y/W + \sin\phi\,\cos\theta)$$

$$a_z = g\,(F_z/W + \cos\phi\,\cos\theta)$$

Rotational Degrees of Freedom:

$$p = d_1\,M_x + d_{12}\,M_y + d_{13}\,M_z$$

$$q = d_{12}\,M_x + d_2\,M_y + d_{23}\,M_z$$

$$r = d_{13}\,M_x + d_{23}\,M_y + d_3\,M_z$$

Body Axis Force:

$$F_x = QS\,\Sigma\,C_{xi} + \cos\epsilon\;\Sigma\,T_i$$

$$F_y = QS\,\Sigma\,C_{yi}$$

$$F_z = QS\,\Sigma\,C_{zi} + \sin\epsilon\;\Sigma\,T_i$$

Body Axis Moment:

$$M_x = QSb\;\Sigma\;C_{\ell i} + \sin\,\Sigma\,\ell_{yi}\,T_i$$
$$+ F_y\,(\Delta z_{cg}) - F_z\,(\Delta y_{cg}) + q\,\sin\epsilon\,\Sigma\,I_e\,\omega_{ei}$$
$$+ (I_y - I_z)qr + p(qI_{xz} - rI_{xy}) + (q^2 - r^2)I_{yz}$$

$$M_y = QS\bar{c}\;\Sigma\;C_{mi} + \Sigma\,\ell_{\overline{T}_i}\,T_i$$
$$+ F_z\,(\Delta x_{cg}) - F_x\,(\Delta z_{cg}) - (r\,\cos\epsilon + p\,\sin\epsilon)\,\Sigma\,I_e\,\omega_{ei}$$
$$+ (I_z - I_x)\,pr + q\,(r\,I_{xy} - pI_{yz}) + (r^2 - p^2)\,I_{xz}$$

$$M_z = QSb\;\Sigma\;C_{ni} + \cos\epsilon\,\Sigma\,\ell_{yi}\,T_i$$
$$+ F_x\,(\Delta y_{cg}) - F_y\,(\Delta x_{cg}) + q\,\cos\epsilon\,\Sigma\,I_e\,\omega_{ei}$$
$$+ (I_x - I_y)\,pq + r\,(pI_{yz} - qI_{xz}) + (p^2 - q^2)\,I_{xy}$$

Figure 8a Aircraft Equations of Motion

Weight and Inertia:

$$I_x = \Sigma I_{xi} \quad I_y = \Sigma I_{yi} \quad I_z = \Sigma I_{zi}$$

$$I_{xy} = \Sigma I_{xyi} \quad I_{yz} = \Sigma I_{yzi} \quad I_{xz} = \Sigma I_{xzi}$$

$$\dot{W} = \Sigma W_i$$

$$\det I_n = I_x I_y I_z - 2I_{xy} I_{xz} I_{yz} - (I_x I_{yz}^2 + I_y I_{xz}^2 + I_z I_{xy}^2)$$

$$d_1 = (I_y I_z - I_{yz}^2)/\det I_n$$

$$d_2 = (I_x I_z - I_{xz}^2)/\det I_n$$

$$d_3 = (I_x I_y - I_{xy}^2)/\det I_n$$

$$d_{12} = (I_{yz} I_{xz} + I_{xy} I_z)/\det I_n$$

$$d_{13} = (I_{xy} I_{zy} + I_{xz} I_y)/\det I_n$$

$$d_{23} = (I_{xy} I_{xz} + I_{yz} I_x)/\det I_n$$

Velocity Vector Orientation:

$$V_T = \sqrt{u^2 + v^2 + w^2}$$

IF $V_T = 0$, $\beta = \beta_{LAST}$

IF $V_T \neq 0$

$$\beta = \sin^{-1}\left(\frac{v}{V_T}\right)$$

IF $u^2 + w^2 = 0$, $\alpha = \alpha_{LAST}$, $\dot{\alpha} = \dot{\alpha}_{LAST}$, $\dot{\beta} = \beta_{LAST}$

Figure 8b Aircraft Equations of Motion (Cont'd)

$$\text{IF } u = \sqrt{u^2 + w^2}\,, \quad \alpha = 180°$$

$$\text{IF } u \neq -(u^2 + w^2)$$

$$\alpha = 2 \tan^{-1} \left\{ \frac{w}{u + \sqrt{u^2 + w^2)}} \right\}$$

$$\dot{\alpha} = \frac{a_x u - a_x w - v\,(pu + rw)}{(u^2 + w^2)} + q$$

$$\beta = \frac{a_y (u^2 + w^2) - v\,(a_x u + a_z w) + V_T^{\,2}\,(pw - ru)}{V_T^{\,2}\,\sqrt{u^2 + w^2}}$$

Earth Axis Orientations by Quaternions

Body axis rate derivatives

$$\dot{u} = a_x + (rv - qw)$$

$$\dot{v} = a_y + (pw - ru)$$

$$\dot{w} = a_z + (qu - pv)$$

Obtain by integration

$$u,\ v,\ w,\ p,\ q,\ r,\ \psi,\ \theta,\ \phi$$

$$X,\ Y,\ h$$

Atmosphere dependent quantities

$$M = V_T / a$$

$$Q = (Q/m^2)\ M^2$$

Figure 8c Aircraft Equations of Motion (Cont'd)

Wind axis orientation parameters are also defined so as to allow the aircraft to undergo very large angular displacements without causing discontinuities in key aerodynamic data table ordinates.

2.2.1.3 Coordinate Frame Rotations

This simulator needs to compute the matrix of body frame orientation in space. When a frame is observed to be rotating with (vector) rate $\overline{W}$ relative to a stationary reference, the time history of transformation C(t) will be the solution of:

$$\dot{C} + \Omega C = 0_3 \qquad C(to) = Co$$

where   is an array of entries which are components of $\overline{W}$.

This system requires the solution of six differential equations to obtain C(t). An alternative method, the Cayley-Klein[1] parameters, requires the solution of four differential equations driven at one half the rate of the above system.

This alternate system of equations is obtained by considering an arbitrary vector $\overline{V}$, constant in the reference frame "S" and transformed into the rotating frame "R" by C(t):

$$C(t)\{\overline{V}\}_s = \{\overline{V}\}_r \quad ; \quad \{\overline{V}\}_s \triangleq \begin{bmatrix} U \\ V \\ W \end{bmatrix} \qquad \{\overline{V}\}_r \triangleq \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

Then let the vector components be displayed by the two-dimensional square matrices of complex entries:

$$S \triangleq \begin{bmatrix} w & u-jv \\ u+jv & -w \end{bmatrix} \qquad R \triangleq \begin{bmatrix} z & x-jy \\ x-jy & -z \end{bmatrix}$$

and find the matrix Q which will "rotate" S into R by the similarity transformation:

$$R = Q\,S\,Q^*$$
$$Q = Q^* = 1_2$$
$$\det Q = +1$$

The determinant of S is $-||V||^2$ and since it is invariant with similarity transformation, S has been orthogonally transformed to R (or "rotated").

---

[1] This method leads to the quaternion equations of coordinate rotation. Its feature is that the derivation requires no new mathematematic notation or algebra.

Computation of $\frac{d}{dt}R$ from the consideration of $\frac{d}{dt_s}\bar{V} = \bar{\emptyset} = \frac{d}{dt}R\ \bar{V} + \bar{W} \times \bar{V}$, and equating the above with:

$$\frac{d}{dt}(QSQ^*) = \dot{Q}Q^*R + (\dot{Q}Q^*R)^*$$

produces the differential equations for the entries of Q. From constraints shown above, the matrix Q is restricted to the form:

$$Q \triangleq \begin{bmatrix} (e_1 + je_2) & (e_3 + je_4) \\ -(e_3 + je_4)^* & (e_1 + je_2)^* \end{bmatrix}$$

Equating reals and imaginaries of the first row of

$$R = Q\ Q^*\ R + (Q\ Q^*\ R)^*$$

will give the system of equations:

$$\dot{\underline{e}} = [\psi]\ \underline{e} \qquad \underline{e} \triangleq \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \end{bmatrix}$$

$$[\psi] \triangleq 1/2 \begin{bmatrix} 0 & -r & -q & -p \\ r & 0 & -p & q \\ q & p & 0 & -r \\ p & -q & r & 0 \end{bmatrix}$$

The matrices Q, 2 x 2, and C, 3 x 3 are functionally related by their definitions

$$Q:\ R = Q\ S\ Q^*$$

$$C:\ \{\bar{V}\}_r = C\ \{\bar{V}\}_s$$

so that:

$$\begin{aligned}
e_1^2 - e_2^2 - (e_3^2 - e_4^2) &= C_{11} \\
2(e_1e_2 + e_3e_4) &= C_{12} \\
2(e_2e_4 - e_1e_3) &= C_{13} \\
2(e_2e_2 - e_2e_2 &= C_{21} \\
(e_1 - e_2 + e_3 - e_4) &= C_{22} \\
2(e_1e_4 + e_2e_3) &= C_{23} \\
2(e_1^2e_3^2 + e_2^2e_4^2) &= C_{31} \\
2(e_2e_3 - e_1e_4) &= C_{32} \\
e_1 + e_2 - (e_3 + e_4) &= C_{33}
\end{aligned}$$

This allows the solution of the differential equation above

($\dot{\underline{e}} = [\psi]\underline{e}$) as:

$$\underline{e}(t) = \underline{e}(t_0) + \int_{t_0}^{t} \dot{\underline{e}}dt$$

where e(t) is obtained from the values of cij(t) above.

2.2.2 Control System Digitization

For reasons of run efficiency, reliability, and repeatability, a highly flexible means of digitally representing aircraft control systems of greatly varying degrees of linearity is required. The detailed mathematics of just such a control system representation is presented in Reference (m). That approach is described in this section.

The control system is described as a unit having a flexible number of inputs and outputs. The system is further partitioned into successive non-linear and linear stages connected by arbitrarily definable internal variables. Boundaries of these stages are chosen so that all successive linear or non-linear block elements in all control channels are grouped together.

2.2.2.1 Non-linear Stages

Each non-linear stage contains all scheduling, limiting and switching functions as well as any algebraically expressible functions not obeying linear system superposition. Possibilities for such operations are virtually limitless and therefore no general formulation is available. Maximum flexibility is achieved by storing all numerical values associated with non-linear stages in input tables allowing for easy changes to such values. However, logic changes will inevitably require programming changes. Each stage is compartmentalized into a seperate subroutine. Many alternate stages may be contained in the source program and conditionally called based on values of control integers. By doing so it is possible to rapidly effect control system logic changes without recompilation. Reprogramming is necessary only if new control logic is required.

2.2.2.2 Linear Stages

Linear stages consist of a grouping of elements, usually from several different control channels, which are described by transfer functions. Any network of such elements may be reduced by block diagram algebra to a form consistent with the transfer matrix equation.

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \cdot \\ \cdot \\ \cdot \\ Y_j \end{bmatrix} = \begin{bmatrix} G_{11} & G_{12} & \cdots & G_{1K} \\ G_{21} & G_{22} & \cdots & G_{2K} \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ G_{j1} & G_{j2} & \cdots & G_{jK} \end{bmatrix} \begin{bmatrix} U_1 \\ U_2 \\ \cdot \\ \cdot \\ \cdot \\ U_K \end{bmatrix}$$

The transfer function entries of G above represent continuous elements while the digital computer may operate only with sampled signals. Therefore the computer must assume some variation of the inputs and outputs between sampling instants.

This is accomplished by use of the Tustin transformation.

$$S = \frac{2}{T_s} \frac{(z-1)}{(z+1)}$$

which implies a straight line variation between sampling instants.

The equations representing the linear stage are further compacted for computational efficiency into the state space forms.

$$\bar{Y}(t) = (C\ \bar{X}\ (t) + D\ \bar{U}(t)$$
$$\bar{X}(t) = A^*\ \bar{X}\ (t-T) + B\ \bar{U}(t-T)$$

The state space matrices A*, B, C, D are determinable from the gains, poles, zeroes, and subscripts of the entries of the transfer function matrix. The mathematics involved is extensive and presented in reference (m).

Using this approach any linear stage may be changed completely by changing input data tables.

2.2.2.3 F-14 Control System Diagrams

F-14 control systems currently of interest are partitioned into non-linear and linear stages consistent with the previously described modeling approach. System A represents the F-14 control system as it currently exists on fleet aircraft. System B incorporates modifications suggested by NASA Langley and implemented for flight testing at NASA Dryden in January 1980.

2.2.2.4 Control System Schematic Representation

The entire control system is described in the following diagrams. Non-linear stages appear as Figures 9 through 14. The associated Linear stages appear in Tables IV through VIII.

For definition of the symbology used in these figures refer to Table II (Section 1.7).

CONTROL SYSTEM DIAGRAMS

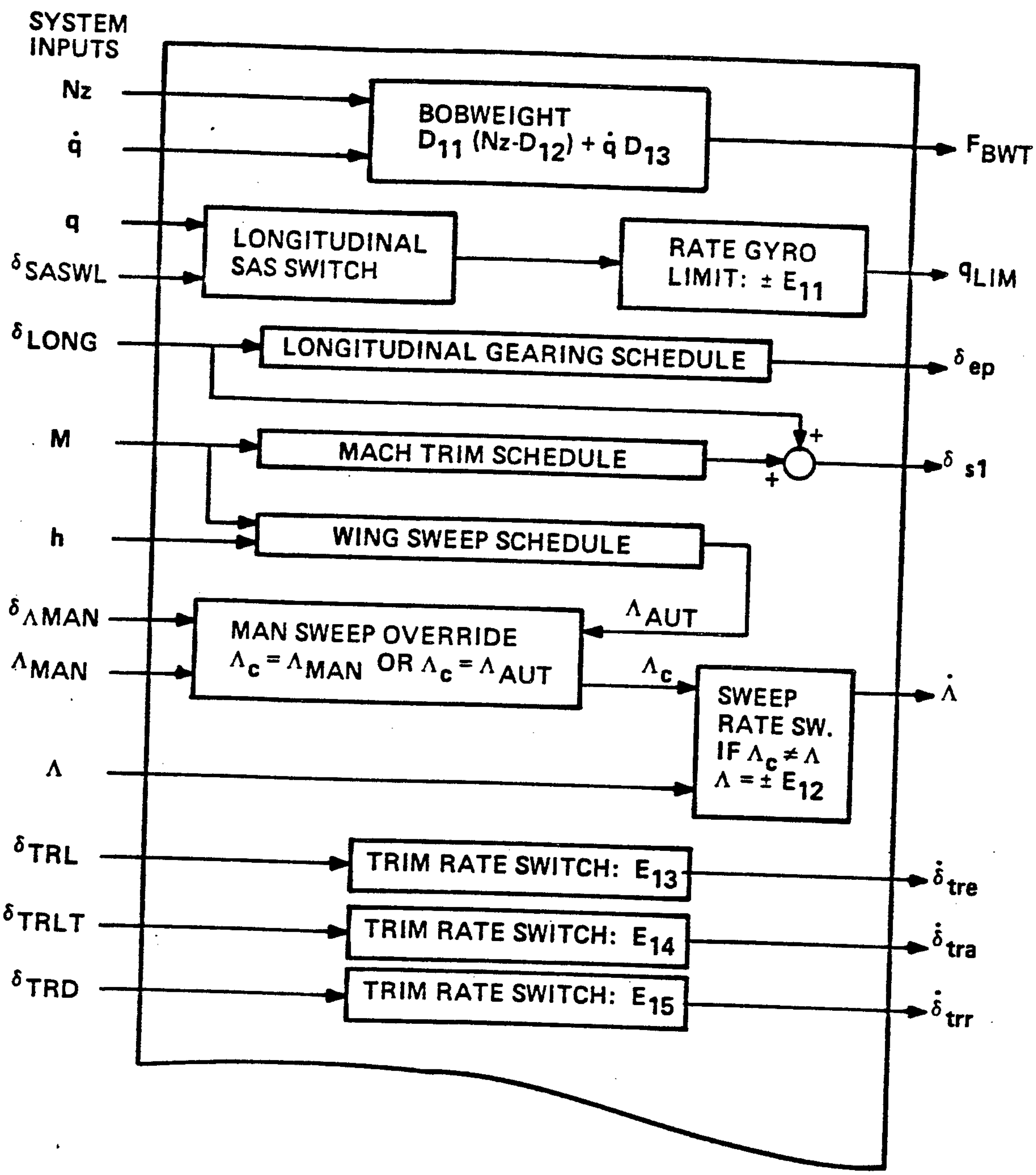


FIGURE 9(a) Control System A: First Nonlinear Stage

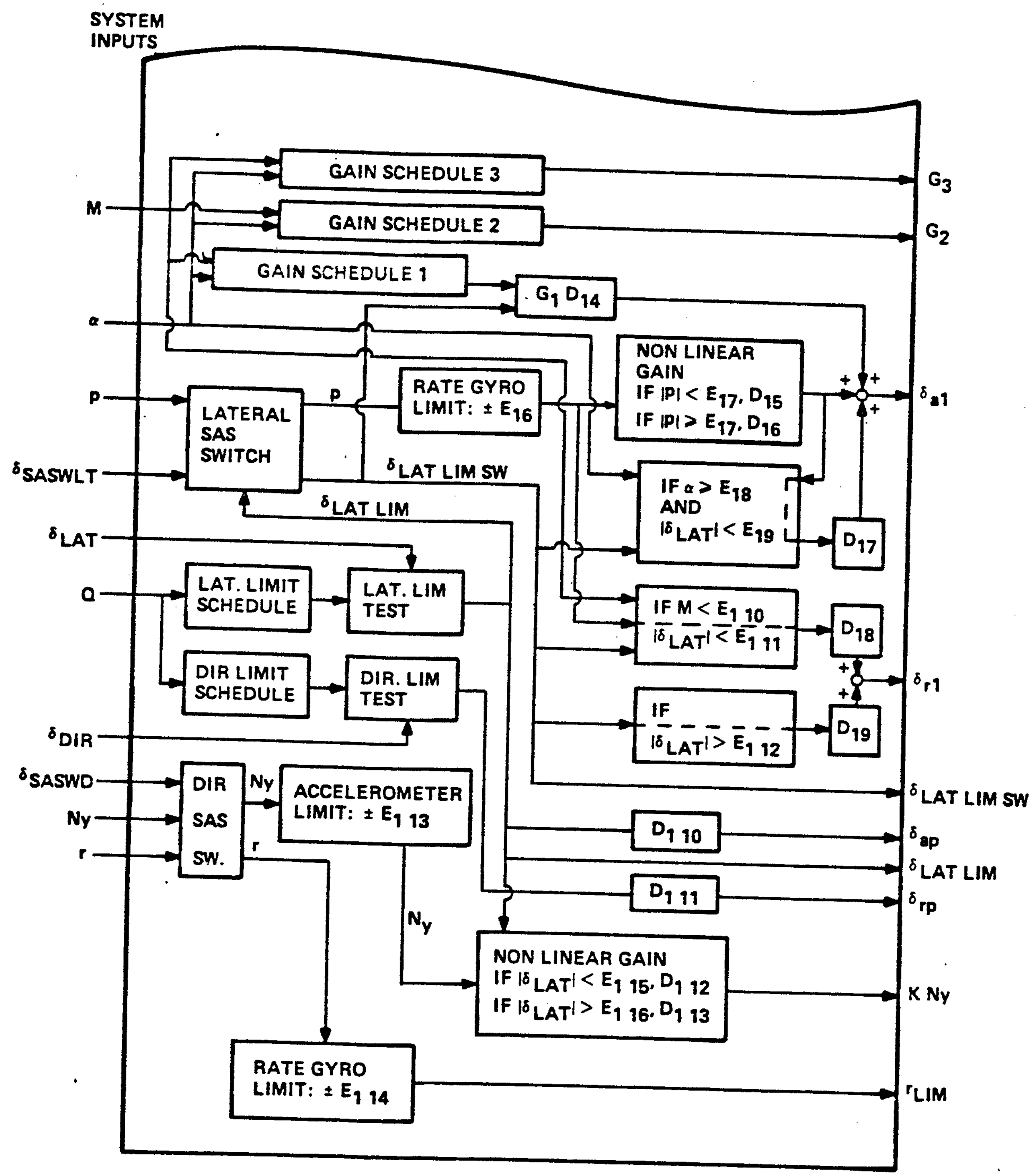


FIGURE 9(b) Control System A: First Nonlinear Stage (Cont.)

TABLE IV

CONTROL SYSTEM A: FIRST LINEAR STAGE

FIRST LINEAR STAGE

INPUTS:

U_1	U_2	U_3	U_4	U_5	U_6	U_7	U_8	U_9
q_{LIM}	δr_2	δ_{LAT} LIM SW	K Ny	r_{LIM}	$\dot{\delta}_{tre}$	$\dot{\delta}_{tra}$	$\dot{\delta}_{trr}$	$\dot{\Lambda}_{MAN}$

OUTPUTS:

y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9
δeq_1	δr_2	δa_2	δr_3	δr_4	δ_{tre}	δ_{tra}	δ_{trr}	Λ_{MAN}

Transfer Matrix entries:

$$G_{11} = \frac{S}{S+.5} \qquad G_{22} = \frac{8.}{S+8.} \qquad G_{33} = \frac{8.56}{S+2.}$$

$$G_{44} = \frac{20.}{S+20.} \qquad G_{55} = \frac{S}{S+.5} \qquad G_{66} = \frac{1}{S}$$

$$G_{77} = \frac{1}{S} \qquad G_{88} = \frac{1}{S} \qquad G_{99} = \frac{1}{S}$$

Engine dynamic model

u_{10}	u_{11}	u_{12}	u_{13}
δ_{THL}	E_{26}	δ_{THr}	E_{26}
y_{10}	y_{11}	y_{12}	y_{13}
δ_{THL1}	δ_{THL2}	δ_{THr1}	δ_{THr2}

$$G_{10\,10} = G_{12\,12} = \frac{1}{S+2.} \qquad G_{11\,11} = G_{13\,13} = \frac{1}{S+5.}$$

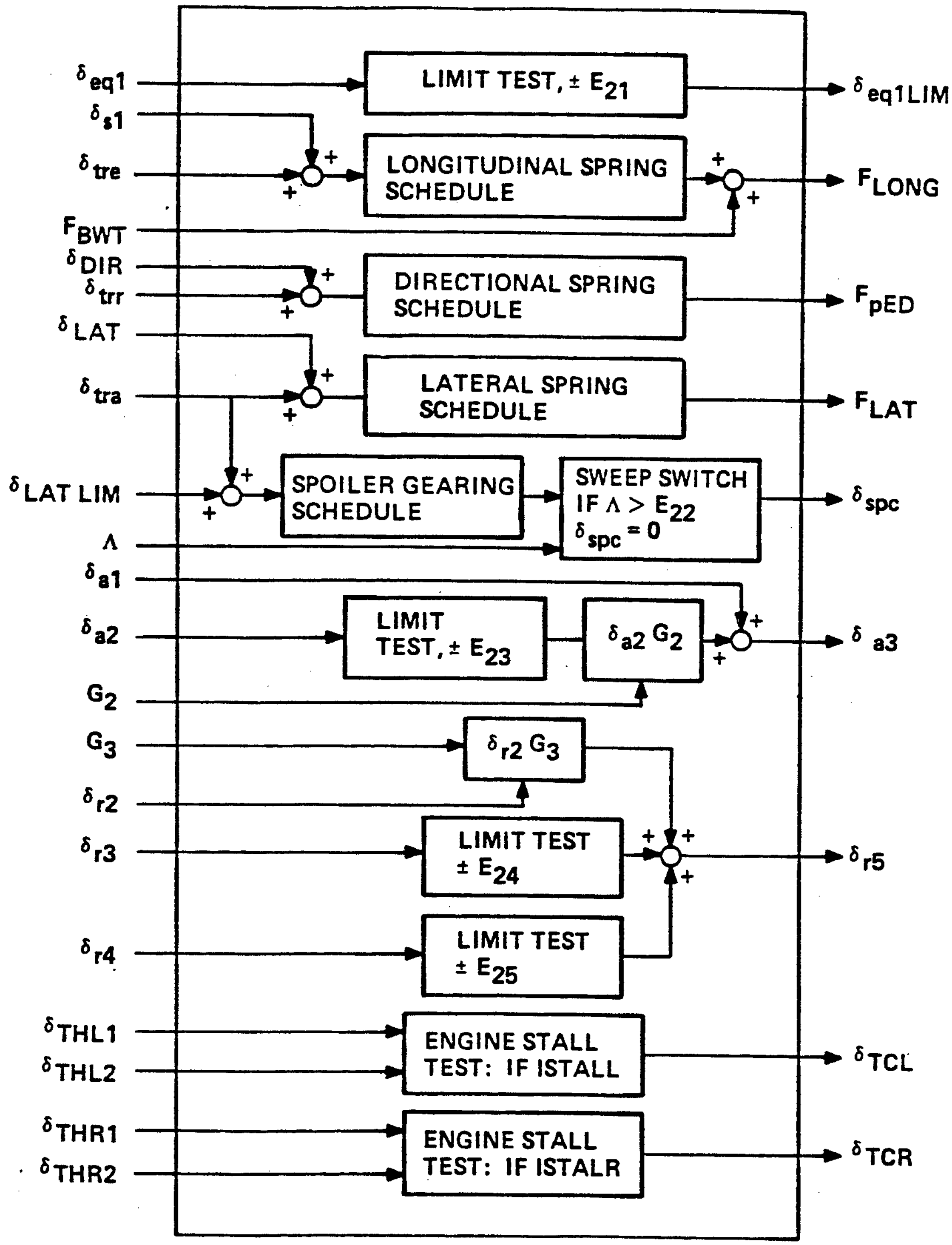


FIGURE 10. Control System A: Second Nonlinear Stage

TABLE V

CONTROL SYSTEM A.
SECOND LINEAR STAGE

INPUTS:

u_1	u_2	u_3	u_4	u_5	u_6	u_7
$\delta eq1$ LIM	δ_{a3}	E_{32}	δspc	E_{34}	δr_5	E_{36}

OUTPUTS:

y_1	y_2	y_3	y_4	y_5	y_6	y_7
δeq_2	δa_4	δa_5	δsp	δsp_1	δr_6	δr_7

Transfer Function Matrix:

$$G_{11} = \frac{1.0114\,(S+5)^2}{(S+1.887)\,(S+13.4)} \qquad G_{22} = G_{66} = \frac{90}{(S+90)}$$

$$G_{33} = G_{77} = \frac{90}{S}$$

$$G_{44} = \frac{20}{S+20} \qquad G_{55} = \frac{20}{S}$$

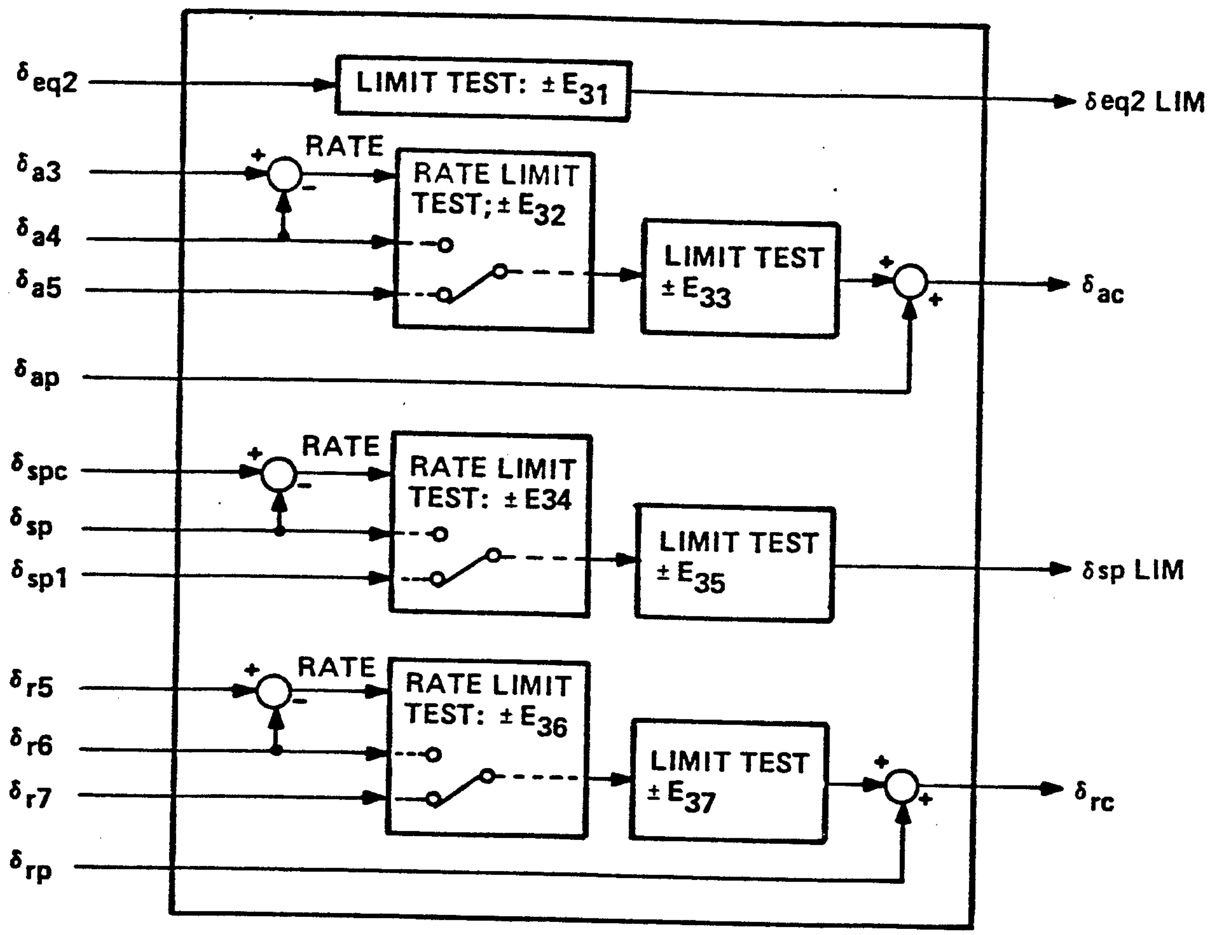


FIGURE 11. Control System A: Third Nonlinear Stage

TABLE VI

CONTROL SYSTEM A: THIRD LINEAR STAGE

INPUTS:

u_1	u_2	u_3
$\delta_{eq2\ LIM}$	δ_{rc}	E_{45}

OUTPUTS:

y_1	y_2	y_3
δ_{eq3}	δ_{r8}	δ_{r9}

Transfer Matrix Entries

$$G_{11} = \frac{66.67}{s+66.67} \quad G_{22} = \frac{2.0}{s+20} \quad G_{33} = \frac{20}{s}$$

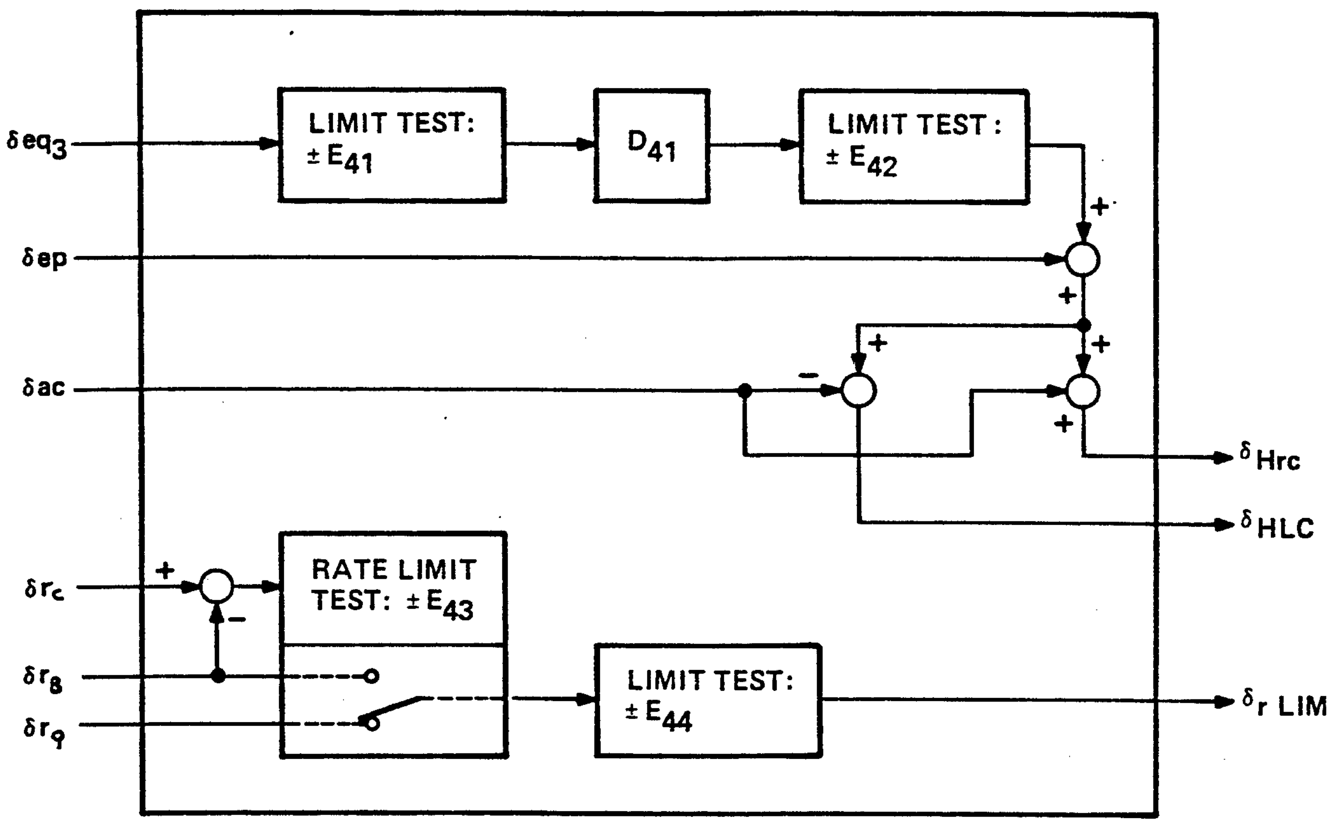


FIGURE 12. Control System A: FOURTH NON-LINEAR STAGE

TABLE VII

CONTROL SYSTEM A: FOURTH LINEAR STAGE

INPUTS	u_1	u_2	u_3	u_4
	δ_{Hrc}	$\pm E_{51}$	δ_{HLC}	$\pm E_{51}$
OUTPUTS	y_1	y_2	y_3	y_4
	δ_{Hr1}	δ_{Hr2}	δ_{HL1}	δ_{HL2}

Transfer Matrix Entries

$$G_{11} = G_{33} = \frac{20}{S+20} \qquad G_{22} = G_{44} = \frac{20}{S}$$

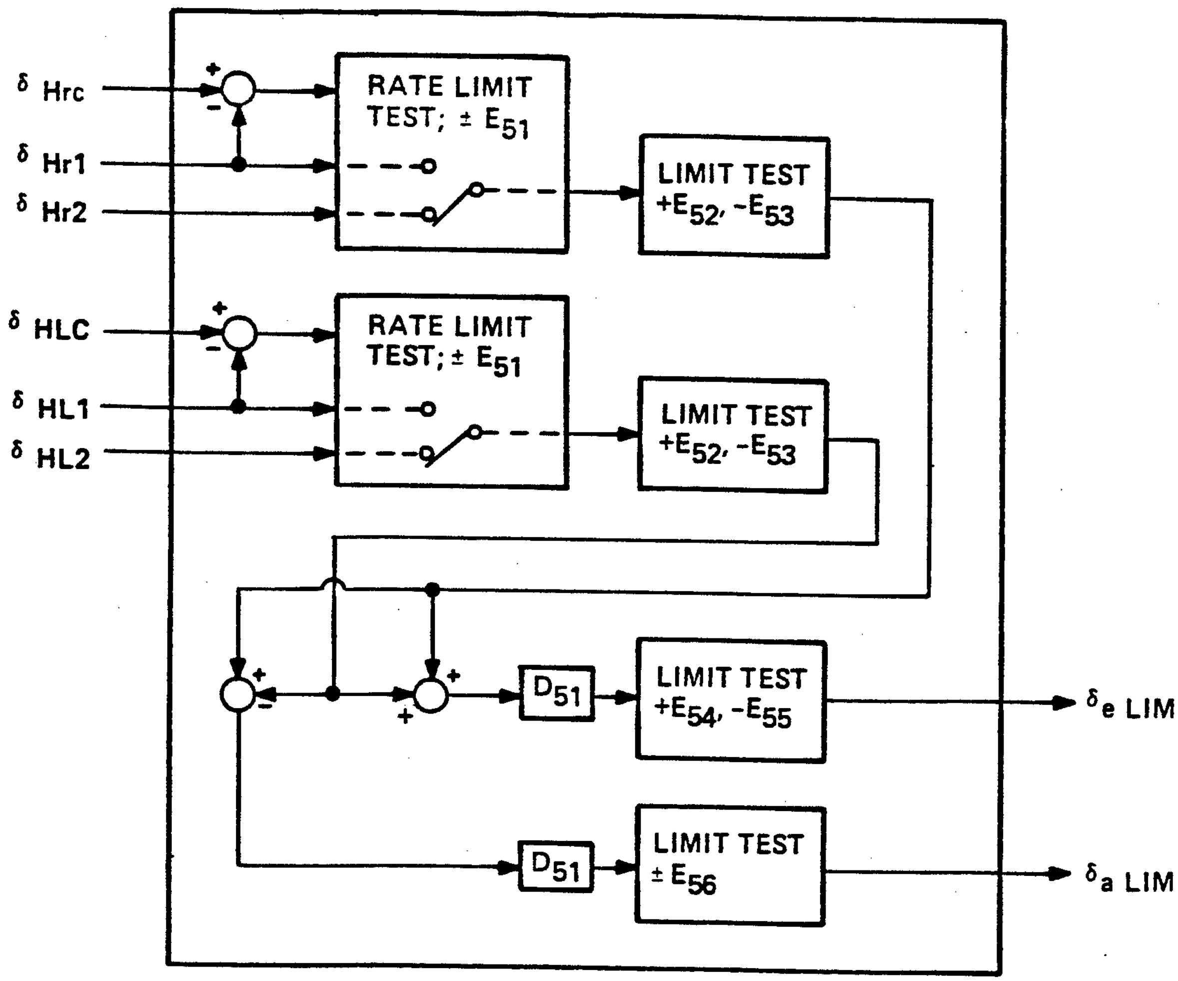


FIGURE 13. Control System A: Fifth Nonlinear Stage

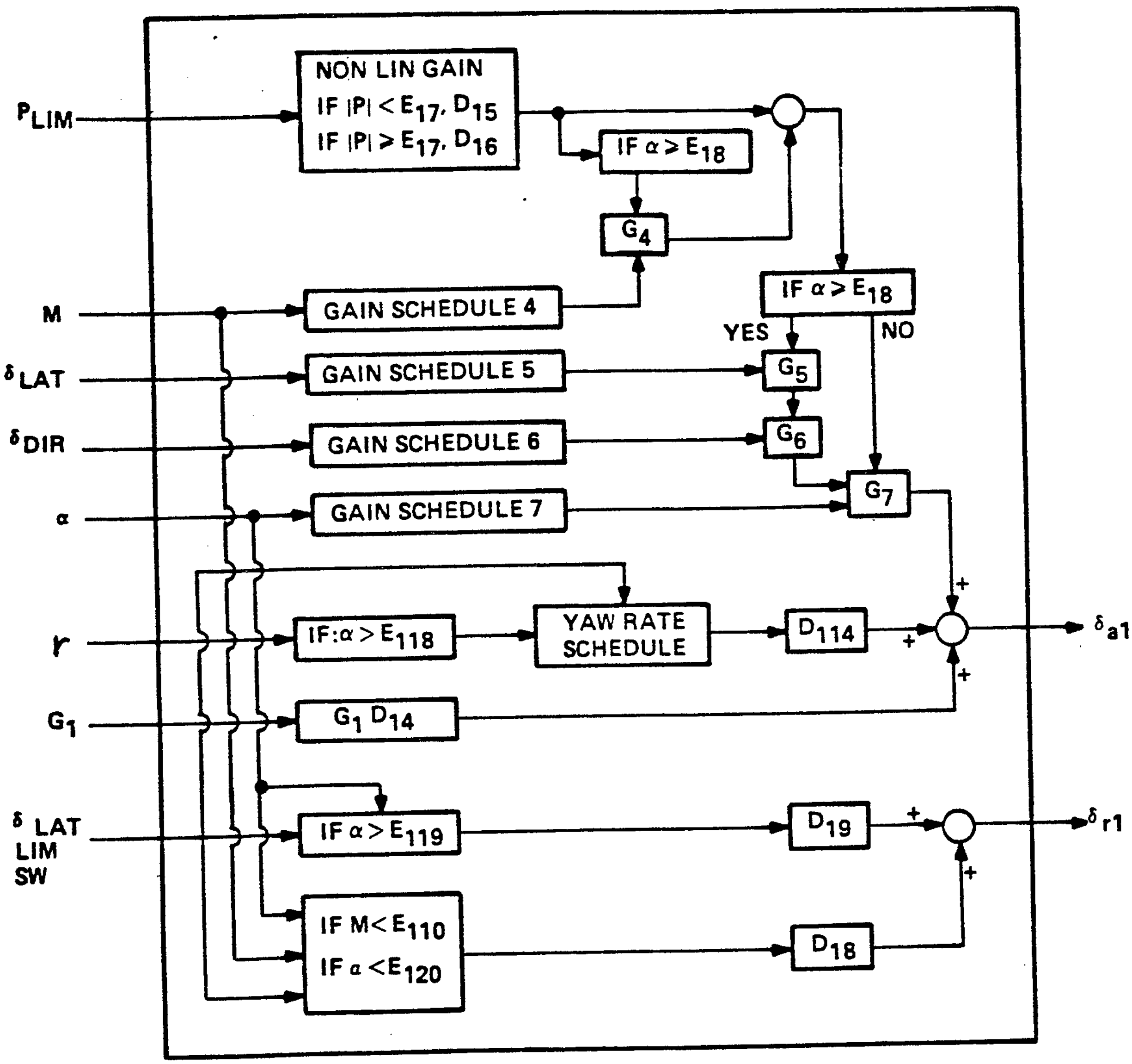


FIGURE 14. Control System B: Modifications To First Nonlinear Stage

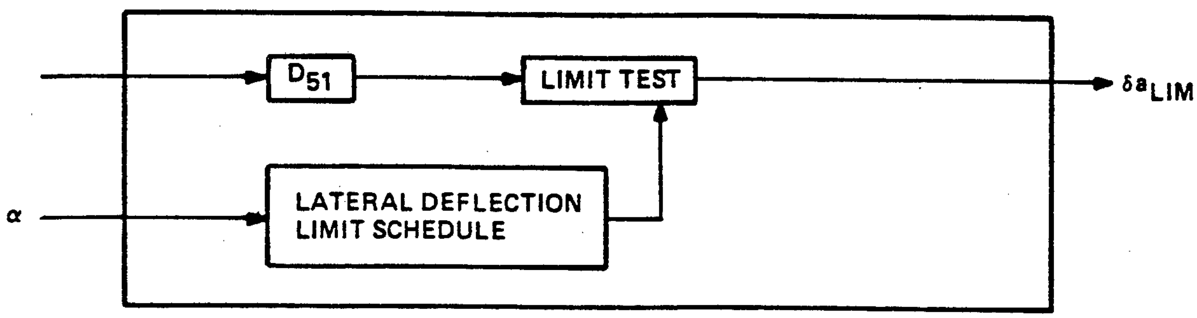


FIGURE 15. Control System B: Modifications To Fifth Nonlinear Stage

CONTROL SYSTEM CONSTANTS

TABLE VIII(a)

CONTROL SYSTEMS A AND B

FIRST STAGE:

E_{11} = .8727 sec^{-1} (50°/sec.)	E_{17} = 2.356 sec^{-1} (135°/sec.)	$E_{1\,13}$ = 1 g.
E_{12} = 15°/sec.	E_{18} = 19°	$E_{1\,14}$ = .8727 sec^{-1}
E_{13} = .5 in/sec.	E_{19} = 1 in.	$E_{1\,15}$ = 1 in.
E_{14} = .19 in/sec.	$E_{1\,10}$ = .55	$E_{1\,16}$ = 1 in.
E_{15} = .113 in/sec.	$E_{1\,11}$ = 1 in.	$E_{1\,17}$ = .35 sec^{-1}
E_{16} = 4.363 sec^{-1} (250°/sec.)	$E_{1\,12}$ = 1 in.	$E_{1\,18}$ = 44°
$E_{1\,19}$ = 25°	$E_{1\,20}$ = 45°	
D_{11} = 3 lb./g.	D_{16} = .15	$D_{1\,11}$ = -10°/in.
D_{12} = 1 g.	D_{17} = 2.	$D_{1\,12}$ = 9.15°/g.
D_{13} = 7.428 lb-sec^2	D_{18} = -38.96°-sec.	$D_{1\,13}$ = 22.5°/g.
D_{14} = 2°/in.	D_{19} = -12.66°/in.	$D_{1\,14}$ = -57.3°-sec.
D_{15} = .04	$D_{1\,10}$ = -2°/in.	

SECOND STAGE:

E_{21} = .2618 sec^{-1} (15°/sec.)	E_{23} = 10°	E_{25} = 21.5°
E_{22} = 55°	E_{24} = 50°	

THIRD STAGE:

E_{31} = .2618 sec^{-1} (15°/sec.)	E_{34} = 12.5°/sec. ($\frac{250°}{20}$/sec.)
E_{32} = .3667°/sec. ($\frac{33°}{90}$/sec.)	E_{35} = 55°
E_{33} = 5°	E_{36} = .7044°/sec. ($\frac{63.4°}{90}$/sec.)
	E_{37} = 19°

TABLE VIII(b)

CONTROL SYSTEM CONSTANTS (Contd.)

FOURTH STAGE:

$E_{41} = .175\ sec^{-1}$ (10°/sec.)	$E_{43} = 5.3°/sec.$ ($\frac{106°}{20}$/sec.)
$E_{42} = 3°$ $E_{44} = 30°$	$D_{41} = 17.19°$-sec. (.3°/°/sec.)

FIFTH STAGE:

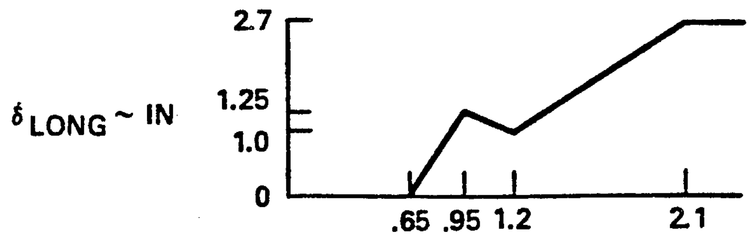
$E_{51} = 1.8°/sec.$ ($\frac{36°}{20}$/sec.)	$E_{53} = 35°$	$E_{55} = -33°$	$D_{51} = .5$
$E_{52} = 15°$	$E_{54} = 10°$	$E_{56} = 12°$	

FOR CONTROL SYSTEM B CHANGE

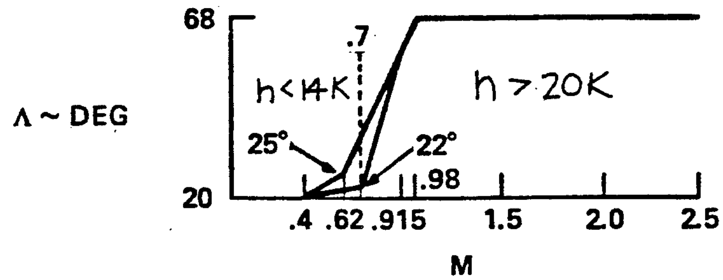
$D_{19} = -6.33°/in.$	$D_{18} = -114.6°$-sec.

CONTROL SYSTEM SCHEDULES

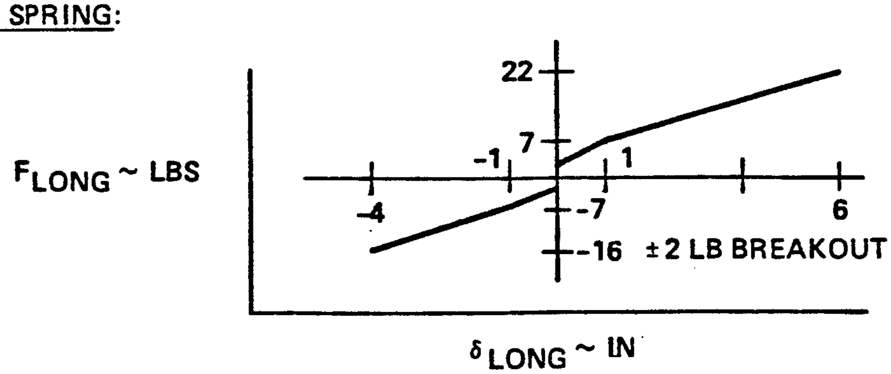
MACH TRIM:



WING SWEEP:



LONGITUDINAL SPRING:



LATERAL SPRING:

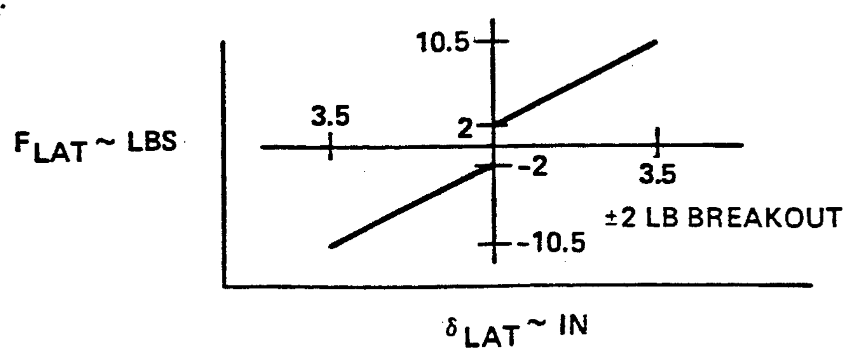
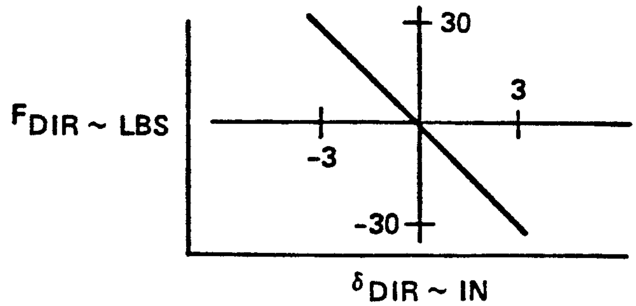
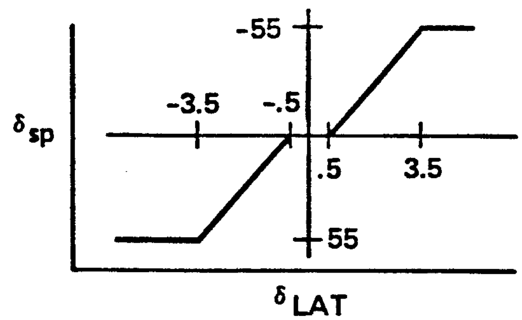


FIGURE 16(a) Control Systems A & B: Schedules

DIRECTIONAL SPRING:



SPOILER GEARING:



GAIN SCHEDULES:

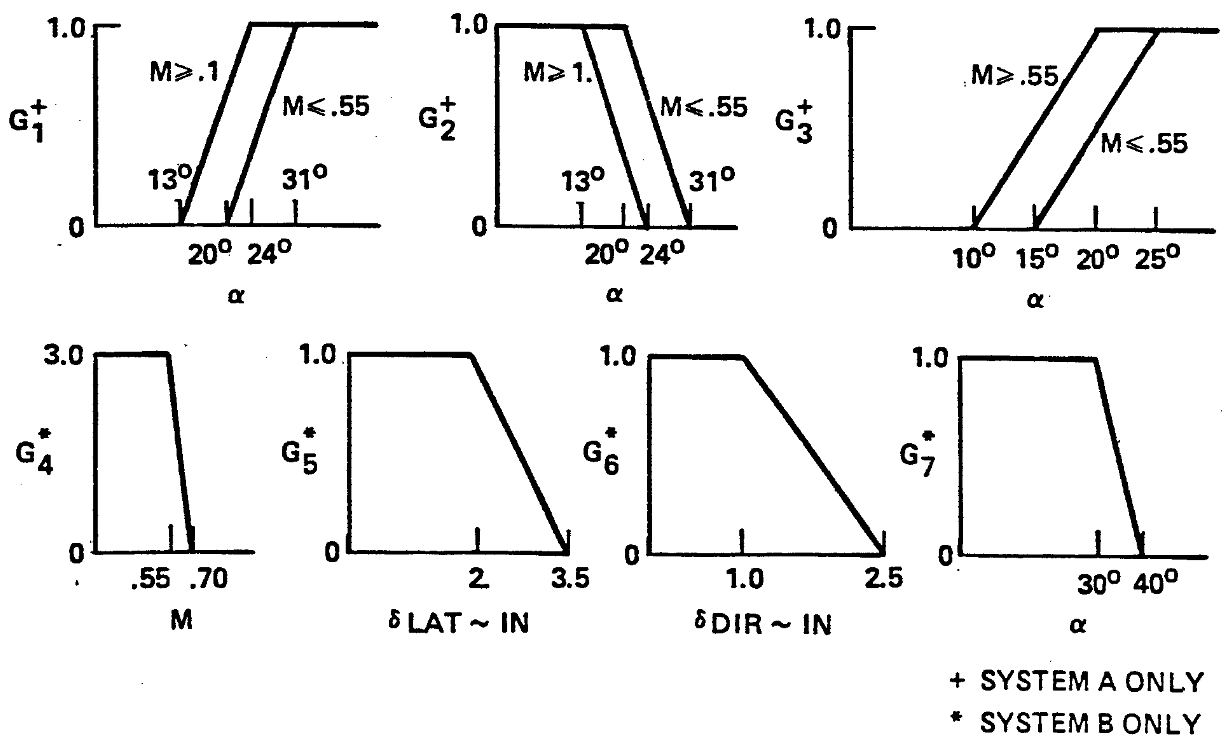
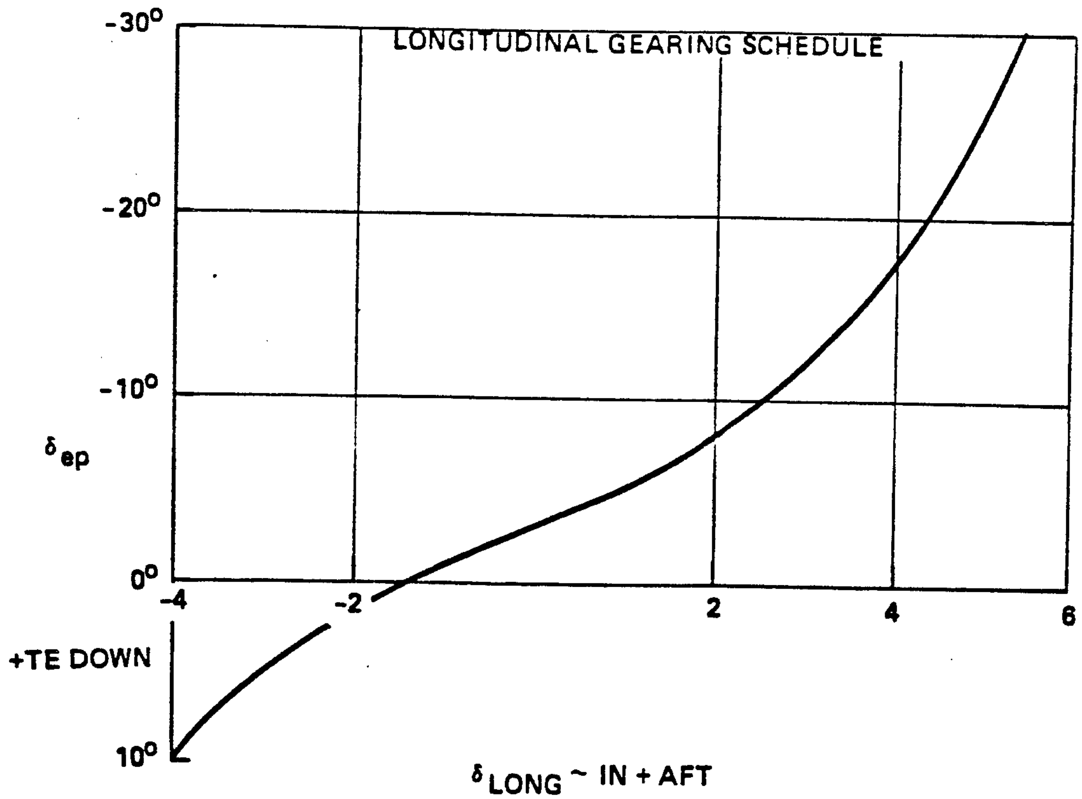
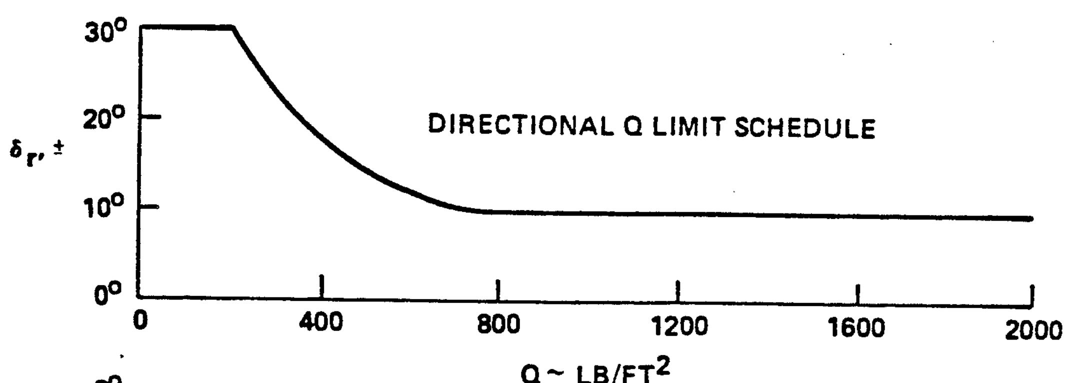


FIGURE 16(b) Control Systems A & B, Schedules (Contd.)





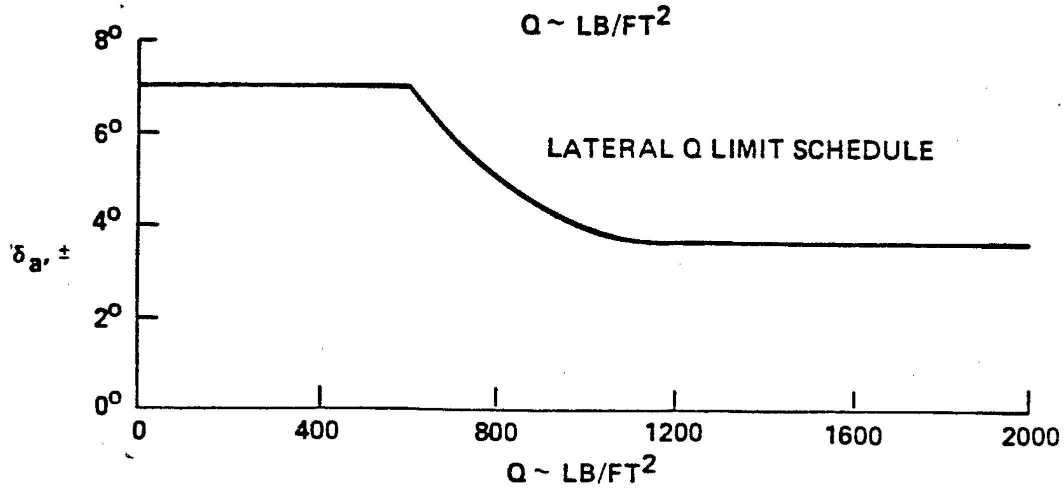
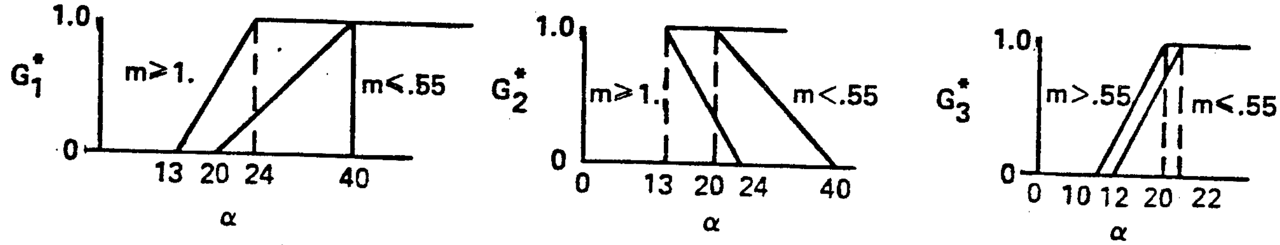
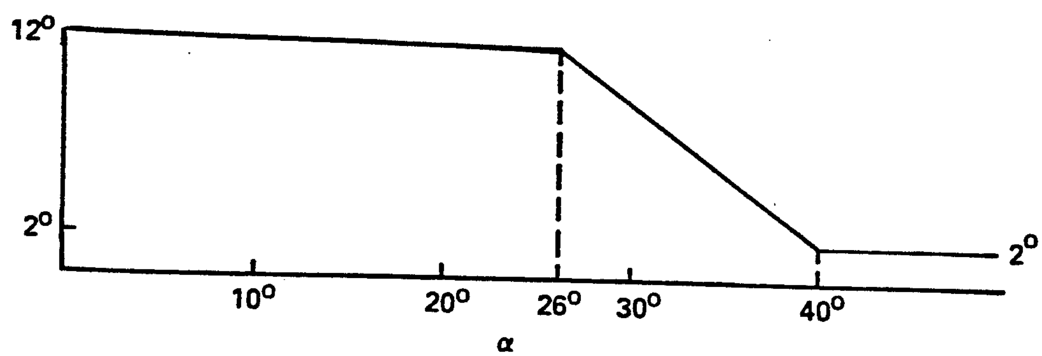


FIGURE 16(c) Control Systems A & B: Schedules (Contd.)

GAIN SCHEDULES



LATERAL DEFLECTION LIMIT



YAW RATE SCHEDULE

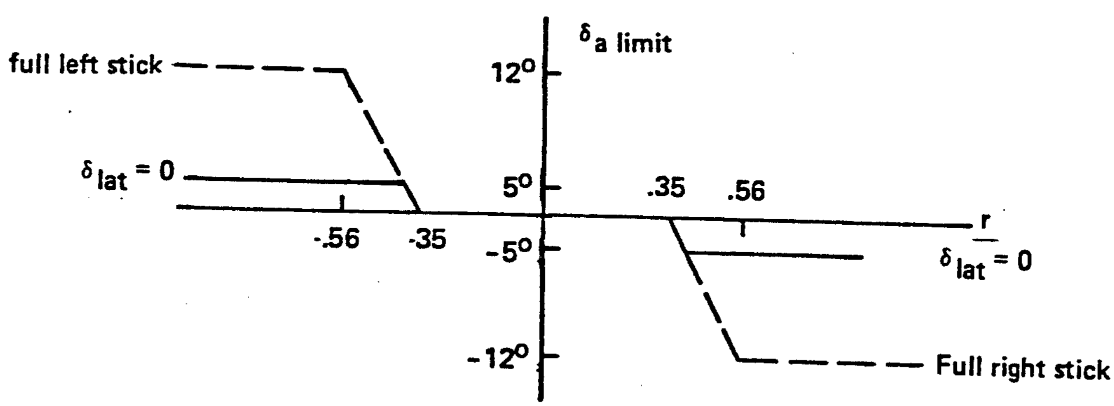


FIGURE 16(d) Control Systems A & B: Schedules (Contd.)

2.3 Dynamic Flight Simulator Equipment Description

The Dynamic Flight Simulator equipment description consists of the detailed specifications and/or functional requirements for the data processing equipment (AREA 1), the crewstation drive equipment (AREA 3), and the crewstation equipment (AREA 5).

2.3.1 Data Processing Equipment

The Data Processing Equipment (AREA 1), highlighted in Figure 17, consists of the CDC 6600 Digital Computer system, several EAI 501 hybrid/analog processors, and a IDIIOM/II Interactive Computer Graphic system.

2.3.1 Digital Processor

The real-time simulation capability of the NAVAIRDEVCEN is resident at the CCS (Central Computer System) in a CDC 6600 series digital computer system. This system was developed for the NAVAIRDEVCEN and is specifically tailored to the Center's requirements. The system provides the capability of simultaneously processing various real-time simulation programs concurrently with the processing of batch jobs, multi-user interactive jobs via remote terminals, graphics, and automatic test-data acquisition and processing.

The system consists of two CDC 6600 central processing units (CPUs), ten peripheral and control processors and a complement of peripheral equipment, most of which can be time-shared by the computers. The interconnection scheme enables the central processor, an extremely high-speed arithmetic processor, to communicate only with central memory while the smaller, slower peripheral and control processors communicate with both central memory and the peripheral devices. This permits the central processor to continue high-speed computations while the peripheral and control processors do the slower I/O and supervisory operations.

The real-time requirements are satisfied by: two hardware real-time monitors (HRTM's), one per CPU, which initiate real-time operation in response to interrupts using the least-time-to-go algorithm; four direct analog/discrete input/output systems (DADIOS) which send and receive data from NAVAIRDEVCEN's real-time equipment; and a read-write bus adaptor to interface between the DADIOS, HRTMs, and central memory.

The spin simulation will use the real-time B-machine at the CCS in a dedicated mode for the formal exercise program. The B-machine runs under a modified SCOPE operating system. The real-time system executive schedules and calls all operational software at rates which are programmable by the user, either by external or internal interrupts. These rates are dependent on:

- the rate of change of the information
- the interrupt processing time required

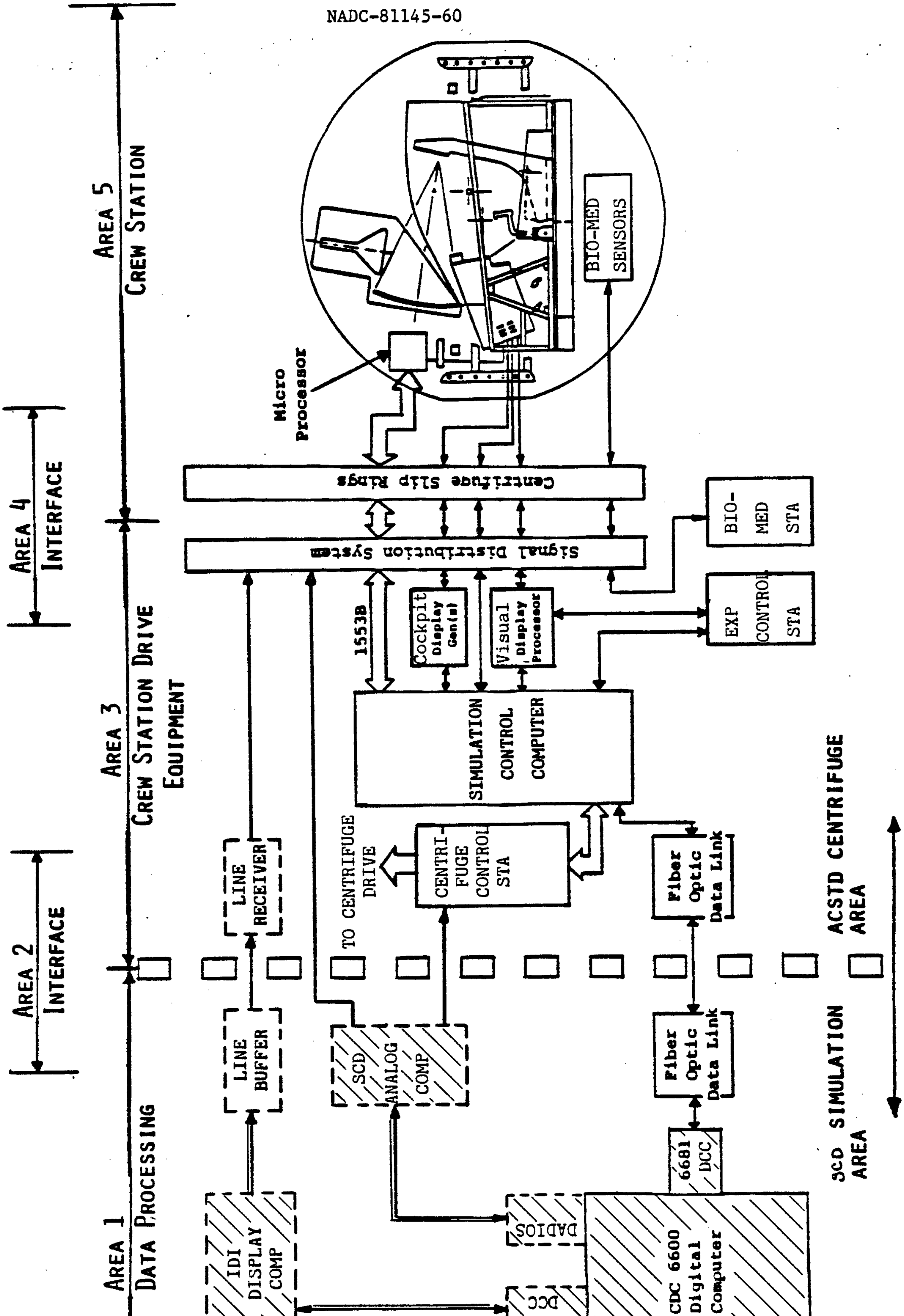


FIGURE 17. DFS DATA PROCESSING HARDWARE EQUIPMENT (AREA 1)

- o the time requirement of equipment requested by the user.

Software development and implementation will utilize the A and B machines of the CCS. The operational software, i.e., the set of computer programs which enables the man-centrifuge system to fulfill its mission requirements, will be created off-line, in UPDATE format, on the A-machine. Test software, resulting from test procedures generated during program design, will be resident in the A and B machines to ensure that the programs being developed meet all specified technical, operational and performance requirements, and acceptance criteria. In addition, support software used to aid the development of the operational and test software is resident on both machines. The B-machine will host copies of the UPDATE files that have completed batch testing. Validation of the software, and system integration of the hardware-software will be performed in real-time, on the B-machine.

2.3.1.2 Hybrid/Analog Processor

The EAI 501 hybrid/analog processors, or Electronic System Simulator (ESS), is a solid-state, 100-volt reference analog machine with parallel digital logic. The analog and digital logic components are programmable through analog and digital patchboards. Each ESS is interfaced with the CDC 6600 via DADIOS, and has the capability for a minimum of 32 channels each of A/D and D/A. Interface with the ACSTD EAI 231R analog centrifuge control computer located in Bldg 70 is via 48 high quality coax lines and approximately 50 low quality telephone lines.

In general, the hybrid/analog machine is used in the simulation of aircraft control and Stability Augmentation Systems (SAS) to take advantage of its continuous solution of complex transfer functions. The F-14 control and SAS will be digitized in the spin simulation; therefore, there is no application for the ESS. It will be considered for signal conditioning and as a backup system for A/D and D/A.

2.3.1.3 SCD Graphics Display System

The SCD display generation capability is resident in the IDIIOM/II (Information Display Inc. Input/Output Machine) interactive computer graphics system located in Bldg 1. The display processor is a Sperry Univac V77 general purpose minicomputer with a 16-bit word length and 32K of core memory, expandable to 64K. Peripheral devices include: a 2.5 million word disk system, an electronic data terminal with keyboard printer, a 9-track magnetic tape unit, a printer-plotter hard copy device, and a CRT display console with electronic alphanumeric and function keyboards and light pen.

The software package includes the HIGHER operating system, a full FORTRAN IV compiler, symbolic assembler, library of mathematical subroutines, debugging package, modular maintenance diagnostic package, and a variety of graphic routines. The display generation capability of the IDIIOM/II includes characters, vectors, dots and circles. There are four character sizes and two

character orientations, normal and rotated 90^{o} CCW. In addition, there are four intensity levels, a steady or blink control, and a provision for line structures of solid, dotted, dashed or dot-dash. The system can drive a maximum of six remote or slave displays, up to a distance of 300 feet.

The SCD Graphics Display System will be linked to the ACSTD Centrifuge Area by buffered video lines. Buffer amplifiers will provide line buffering, offset and gain control. This configuration will provide the capability to drive CRT displays in the gondola from either the SCD display system or the DFS Visual Display System. For the spin simulation, all display software will be programmed on the Simulation Control Computer; therefore, the capability to drive gondola CRTs from the SCD display system will not be utilized.

2.3.2 Crewstation Drive Equipment

The Crewstation Drive Equipment (AREA 3) highlighted in Figure 18, consists of the Simulation Control Computer, a Redifon SP-2 real world visual display generator, three symbol generators, a general purpose analog computer, a Bio-Medical Station, and an Experiment Control Station.

2.3.2.1 DFS Visual Display Processor System

The DFS Visual Display System will produce real-time out-of-the-window scenes of colored lights and surfaces representing the real-world environment. The visual display system will be capable of responding to flight simulator data defining viewing conditions. The system will transform numerical data representing the three-dimensional visual environment into two-dimensional perspective images and then process those images into signals for driving the displays. The visual display system should produce successive images at a rate sufficient to give the impression of smooth motion as the observer, or a moving scene object, changes position and/or attitude. Day/dusk/night ambient illumination, full spectrum colors, landing light illumination, weather effects, and various special effects will be simulated. Selection of and operation in different visual environments is provided for. A combination of pilot and controller inputs routed through the simulator into the visual display processor control overall visual performance during operation.

The DFS visual display system will provide for various support and maintenance functions when not in operation. These functions include new scene modeling and model update, system calibration, system test and diagnosis, and utility tasks associated with the management of data and software on storage media.

For further information refer to Section 2.3.3.2 for a description of the Redifon Visual Display Unit located in the Centrifuge Gondola Crewstation.

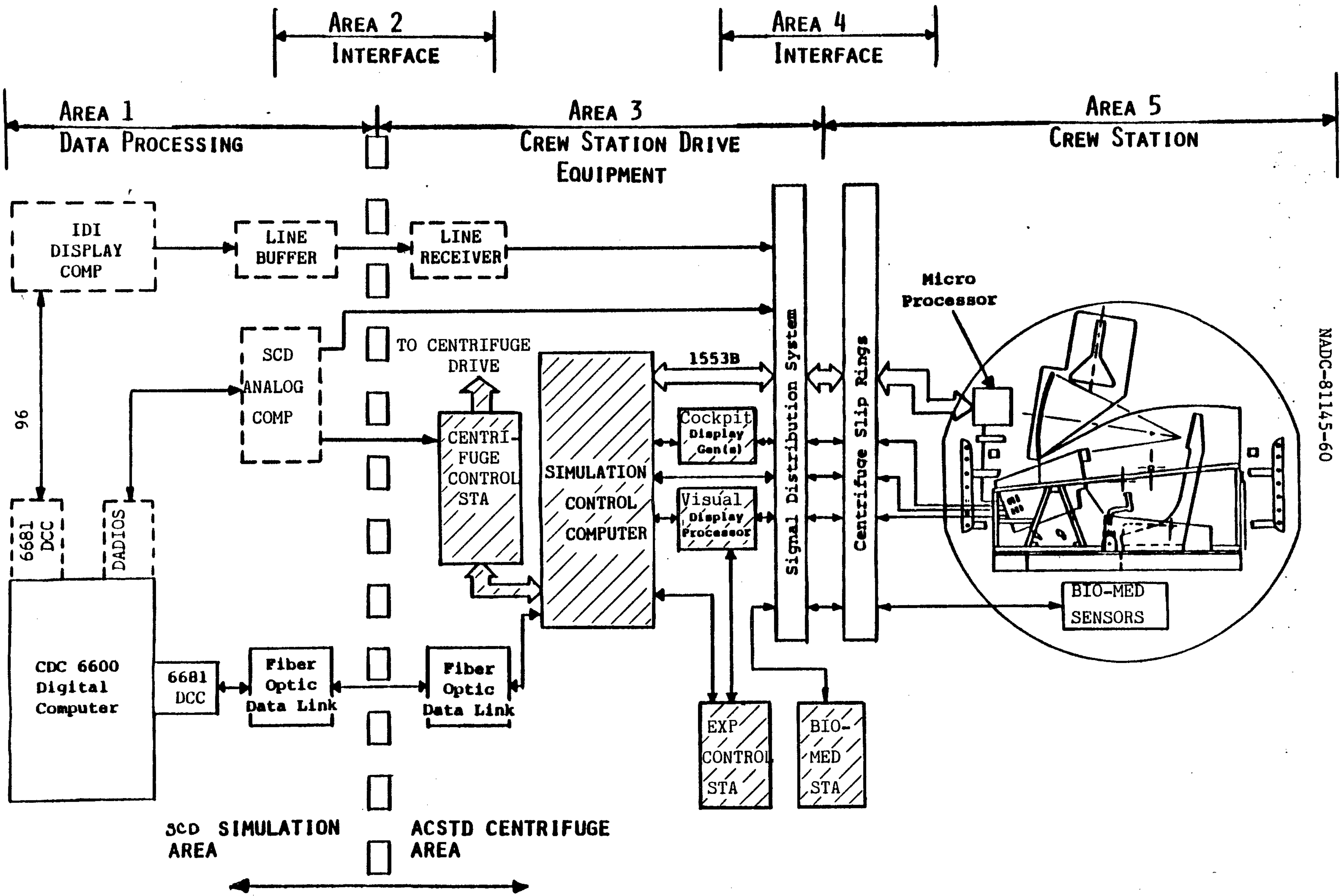


FIGURE 18. DFS CREWSTATION DRIVE HARDWARE EQUIPMENT (AREA 3)

2.3.2.1.1 Operational Capabilities

The visual display system will depict a variety of scene elements consistent with the operational requirements. With respect to flight operations, surfaces may be used to represent:

- Landing area - runways, taxiways
- Buildings
- Terrain features - fields, roads
- Mountains
- Water - ocean, rivers, lakes
- Ground traffic - trucks, airplanes
- Naval vessels
- Ocean markers

Surfaces will be supplied in general detail in surrounding areas for adequate pilot cues when flying at altitude. Surfaces will vary in apparent brightness with ambient illumination.

Light points may be used to represent:

- Naval vessel lighting - decks, approach systems
- Strobe lights
- VASI or BAR
- REIL's
- Flashing obstruction lights - towers
- Directional lights - uni- or bi-directional
- Directional rotating lights - beacons
- Vertical objects - bridges, signs, buildings
- City lighting - general pattern and scatter lights
- Highways, arterial feeds
- Stars
- Moving traffic - cars, other aircraft
- Wave peaks

A large quantity of lights may be used at night where they represent the significant visual cues. In day, lights will be concentrated on the active runway, or naval vessel deck, to assist low visibility approach and landing. Lights will be self-luminous and basically unaffected by ambient scene illumination.

Environmental effects will be seen during flight operations. Certain effects will be inherent in scene processing:

- o Occulting of lights and surfaces by other surfaces
- o Occulting of the sky/horizon band by vertical objects
- o Blue sky overhead with color tapering into fog color at the horizon
- o Light point defocus on near lights to simulate perspective growth
- o Horizon glow band at night
- o Three independently controllable landing light lobe patterns which brighten surfaces when flying at low or 0 altitude.
- o In-cloud glare effects from aircraft landing and aircraft wing tip strobe/anti-collision beacon.
- o Ambient scene illumination - day/dusk/night
- o Visibility - gradual obscuration of scene details with fog
- o Clouds - cloud top and base altitudes determine when cloud ceiling, in-cloud glare, or cloud deck is shown; cloud top and bottom transitions will be gradual depending on rate of climb/descent.
- o Scud - varying visibility below cloud layer
- o Ground fog - altitude, visibility and Runway Visible Range (RVR) controls determine rapid visibility reduction during descent into a ground fog layer
- o Light step intensity control - airfield lights
- o Data base selection - different airfields
- o Stars and/or ground lights obscured - depending on aircraft height and cloud/ground fog conditions.
- o Ambient glare - near ground with RVR
- o Light point defocus - for RVR-related halo

The Computer Generated Image (CGI) specifications are presented in Table IX.

TABLE IX. <u>COMPUTER GENERATED IMAGE SPECIFICATIONS</u>

Scene Detail	
o Lights (points)	1,000 (day) 5,000 (night/dusk)
o Surface (polygons)	450 (day) 225 (night/dusk)
o Edges	512 (day)
Color Capabilities	
o Lights	8 - red, orange, amber, white, blue/white, pale green, green
o Surfaces	64 combinations of red, green, and blue
Special Display Effects	Fog, in cloud, scud, ground fog, continuous or directional horizon option
Power Requirements	230V AC 60 HZ
Scene/Target Content	Scene No. 1: Anytown, USA Scene No. 2: Aircraft Carrier/ Ocean Scene No. 3: Target Aircraft
Operating Software Modes	Online (with host computer) Local (without host computer)

2.3.2.1.2 Functional/Physical Characteristics

The major functional/physical subsystems of the visual display system image generator will consist of:

a. General purpose computer

b. Dual drive floppy disc mass storage system

c. Image Processor (IP) hardware including blowers and built-in-test subsystem for IP diagnostic operation

d. Simulator interface with host Simulation Control Computer

e. System power controller including ac overvoltage and thermal protection, power distribution controls and jacks, and IP power supplies

f. Raster conversion unit (planned)

2.3.2.2 Head-Up Display and Cockpit Display Symbol Generator

Three identical symbol generators will be utilized to generate the formats for the Head-Up Display (HUD), Vertical Display Indicator (VDI), and Horizontal Situation Display Indicator (HSD). The generation of these formats will be in a 525 NTSC Color Format for ease of display, transmission and recording. While a particular symbol generator is yet to be chosen, typical parameters will be as follows:

The symbol generation unit to be utilized with the Head-Up Display, Vertical Display Indicator, and Horizontal Situation Display must be capable of generating the F-14 Aircraft symbology presented in Figures 24, 25 and 26. This unit must also have the capability of being interfaced with the selected HUD, VDI and HSD units as well as the Simulation Control Computer.

The Dynamic Flight Simulator Symbol Generator Unit Specifications are presented in Table X.

TABLE X. Symbol Generator Unit Specifiations

Size of Unit	8" W x 5" H x 24" D (max)
Unit Weight	45 # (max)
Power Requirement	115 ac, 60 Hz, 5A
Resolution	480 by 640 dot matrix
Refresh Rate	30 Hz
Interface Requirements	16 Bit Parallel General Purpose Interface with V77

2.3.2.3 Simulation Control Computer

2.3.2.3.1 General Description

The Simulation Control Computer, a general-purpose microprogrammed minicomputer is based on the Sperry Univac V77-600 computer system. The V77-600 can be used to configure systems having a wide range of application requirements, and provide modular expansion for open-ended system growth, microprogramming for expanded system control, and reliability and easy maintenance for minimum system down time. Also designed to be compatible with existing V70 series software and peripheral hardware and with other V77 family components, the V77-600 is easily adapted to changing system technology.

2.3.2.3.2 Features

A mainframe chassis, control panel, instruction set, and V77-600 processor with hardware multiply/divide, memory parity logic, dual memory buses for dual port memory, I/O bus with direct memory access, and automatic bootstrap loader comprise the standard features of the computer. The mainframe chassis accommodates the control panel, processor, semiconductor memory, option board, expansion hardware for I/O and memory expansion, and other hardware options as required. All of the controls and indicators necessary to operate the computer are located on the control panel. The instruction set contains 201 single and multiple-register instructions. Many instructions can be microcoded to extend the effective repertoire to several hundred microinstructions. The processor has a microinstruction executive time of 165 nanosections and can operate independently from both memory and I/O devices. This processor features eight general-purpose programming registers, eight general-purpose microprogramming registers, 16 bit wide data paths, arithmetic and logical function generators, and data path selection logic which is controlled by microprogramming firmware stored in a programmable read only memory or a writable control store (WCS) option.

The 660 nanosecond semiconductor memory is a dual port, expandable random access, metal-oxide-semiconductor (MOS) memory 65,536 (64K) by 16-bit word modules. When addressed with the megamap option the semiconductor memory system is expandable to 262,144 (256K) words of storage within a single 7-inch mainframe chassis or to 1,048,576 (1024K) words of storage with three additional memory expansion chassis. Full cycle time for this memory without megamap is 660 nanoseconds; access time is 560 nanoseconds.

The common configuration of the V77-600 option board includes I/O bus control logic (with direct memory access), Teletype (TTY) or CRT controller, power failure/ restart (PF/R), and a standard real time clock (RTC). Alternate configurations of the option board may include memory protection (MP) and/or priority memory access (PMA) and/or one of several special (nonstandard) RTC configurations. The option board is also contained in the mainframe chassis which provides connection to I/O expansion and memory expansion chassis.

The V77 system power supply delivers dc power to components located in the mainframe chassis of the computer and peripheral controller boards located in the optional I/O cardframe expansion chassis. Although housed in a separate chassis, the V77 system power supply is turned on or off by the power switch located on the control panel. When the system power supply is turned on, it provides all dc power required by the mainframe processor, option board, megamap option, writable control store option, cache memory option, floating-point processor option, and up to 256K words of 660 nanosecond semiconductor memory. It will also provide sufficient dc power for several peripheral controller boards at the same time.

The V77-600 megamap mainframe option contained on a single board allows the main memory to be expanded to over a million words (two million bytes). In combination with VORTEX II software (see Section 2.4.2.1.4), the megamap option divides the memory into 512-word pages and assigns these to individual application programs on either a contiguous or non-contiguous basis - depending on the most efficient use of the memory available. Memory protection is also provided on a page-by-page basis.

Other computer mainframe options include: priority interrupt module (PIM), buffer interlace controller (BIC), and block transfer controller (BTC). The PIM establishes eight levels of interrupt request on the I/O bus in order of priority. The BIC implements the direct memory access (DMA) capabilities of the basic computer, permitting cycle-stealing I/O data transfers between memory and peripheral controllers at rates of up to 361,800 words per second. The BTC implements automatic data transfers between peripheral controllers and memory via the priority memory access (PMA).

The data-save option is a power-supply option that provides battery power to maintain data in the semiconductor memory during a loss of ac line voltage. A memory of 64K by 16-bit words can be sustained for up to four hours; a larger memory of 256K words for up to two hours. The data-save battery box requires no vertical rack space in the equipment cabinet since it mounts on the rear panel of the power supply. To ensure reliable performance, the three 6-volt series-connected batteries located in the battery box are kept fully charged by circuits in the power supply.

For systems requiring further data-save protection, additional data-save battery packs are available. These battery packs can be used to protect memory above 256K words or can be used in parallel with existing data-save batteries to extend memory protection. Each additional batter pack sustains 256K words of memory of up to 1.5 hours or 64K words for up to 8 hours.

To permit the user to install his own battery pack, a connector at the rear of the system power supply is provided.

The I/O expansion cardframe chassis accommodates connector-planes with a total combined capacity of 24 card slots, cardguide adaptor brackets, and cardguides for up to 23 peripheral controller boards and one I/O connector paddle-board. Connector-planes which are mounted on the rear of a cardframe chassis provide power and I/O bus connections to associated controller

boards. Power connections are made directly from the system power supply to one connector-plane via associated power cables. Power to the other connector-planes are provided through jumper power cables.

The specifications for the Simulation Control Computer (V77-600) are listed in Table XI.

TABLE XI. SIMULATION CONTROL COMPUTER SPECIFICATIONS

Type	General-purpose microprogrammed digital computer.
Memory	Dual-port 660 nanosecond semiconductor memory with 16-bit word length contained in 64K modules with a maximum memory of 1 M words.
Word length	8, 16 or 32 bits.
Register	24 registers: 8 16-bit registers for assembly programming, 8 16-bit general-purpose registers for microprogramming. Seven of the assembly programming registers can be used as index registers (byte, word, or double-word addressing). Four of these same registers can be used as two double-word registers.
Arithmetic	Binary twos complement.
I/O Transfer Rates	DMA (620 compatible): 250,000 words per second. PMA: 1,010,000 words per second (writing). 932,000 words per second (reading).
Instructions	187 standard, can be extended with writable control store. Floating point processor option provides an additional 14 instructions.
Addressing Modes	Byte addressing, word addressing, and double-word addressing, pre-indexed direct or indirect, the 32,768 words using any of the 7 index registers. Direct to 2,048 words. Relative to P,X or B register to 512 words. Pre-indexing with: X or B register. Multilevel indirect to 32,768 words. Indirect indexed. Immediate. Post-indexing with X or B register. Extended mode to 32,768 words. Megamap addressing to 1,048,576 words.
Misc. Features	Mutliply/Divide. Automatic program loader. Memory parity logic. I/O bus with direct memory access. Programmer control panel Power failure/restart Real time clock

Page 1 of 2

Memory protection.
Priority memory access.
Block transfer controller.
Priority interrupt module.
Megamap.
Data-save power supply.
Language processors
  Macro assembler (DASMR)
  FORTRAN IV

Peripherals

Magnetic Disk

- 40 Megaword (unformatted)
- Priority Memory Access

Magnetic Tape

- 9 track
- 800 and 1600 bits per inch.
- Buffer Interlace Controller (Direct Memory Access)

Analog

- A/D
  - 32 single ended channels, 13 bit or 16 differential channels, 13 bit
  - Buffer Interlace Controller
  - Maximum throughput 50,000 samples/sec
- D/A
  - 12 channel, 12 bit
  - Programmed I/O only

Paper Tape

Operator Console

- 300 Baud

IDIIOM Display Unit (Refer to Figure 19)

- Calligraphic
- Priority Memory Access or Buffer Interlace Controller
- 4500 inches of short line segments can be refreshed at 30 frames/second

Page 2 of 2

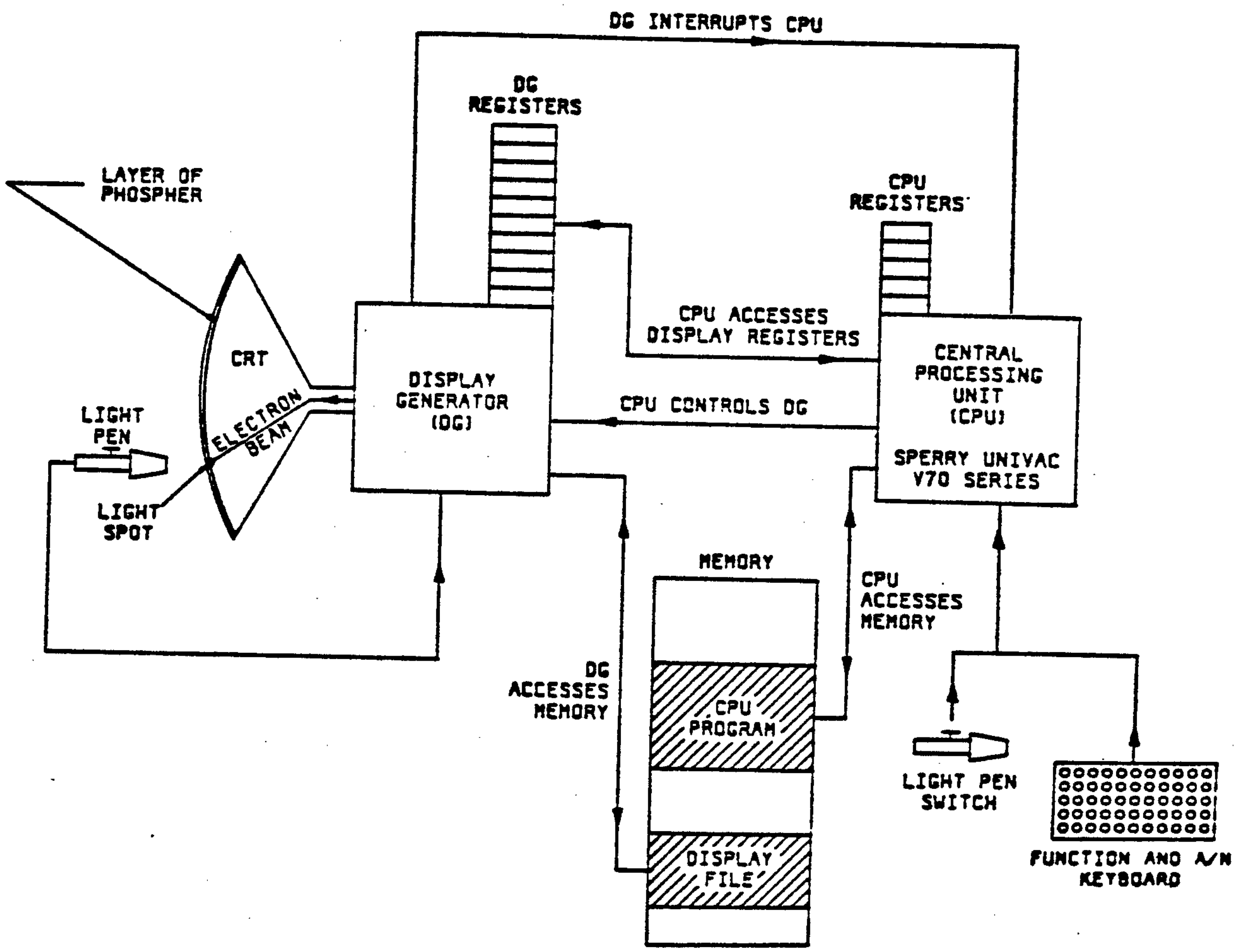


FIGURE 19. IDIIOM DISPLAY UNIT BLOCK DIAGRAM

2.3.2.4 Analog Computer System

Three general purpose analog computers (Electronic Associates Inc. model PACE 231R) are considered part of the centrifuge control system console. Together they have 350 amplifiers with a normal complement of non-linear equipment including electronic multipliers, comparators, limiters, variable and fixed diode function generators. All analog signals to the centrifuge control station are limited and conditioned in these analog computers before being introduced to the motion control system itself. Analog signals sent from the motion control system are likewise conditioned here, both to provide proper signal levels and bandwidth, and to provide the required isolation between the motion control system and the external system. Certain analog data interface control functions are also performed on the analog computer system. These include external system activity detection, motion control transfer logic, and stop request logic for stopping the centrifuge.

2.3.2.5 Biomedical Monitor Station

Biomedical instrumentation and monitoring systems are distinct from the rest of the DFS data collection and control. Standard biomedical monitoring includes a low light level camera view of the pilot's face, two channels of ECG, a cardiotachometer (Hewlett Packard model 78203A), a continuous bidirectional ultrasonic doppler blood flowmeter (L&M model 1012) to measure blood velocity, and an automatic non-invasive arterial blood pressure monitor (DINAMAP). Non-biomedical data optionally available at this station includes the pilot subject g level, g protection suit pressure and other data at the request of the Medical Officer. (Refer to Figure 6)

Analog data is continously displayed on an eight channel storage tube, an eight channel strip chart, and on a video monitor. Since this data is presented to allow a fast medical judgement to be made of the physical condition of the subject pilot, non-essential data should not appear at this station.

2.3.2.6 Experiment Control Station

This station monitors and controls the execution of the simulation experiment. As such, the operator has the ability to request and monitor any data necessary to the simulation. This includes mode and control commands to the SCC, data base change requests to the SCC, out-the-window display changes, and monitoring of certain specified analog signals. This station consists of the following four pieces of equipment as shown on Figure 6 and described below:

2.3.2.6.1 SCC Terminal

This terminal is the operator console for the SCC. It is used for program development and slow input and output during a DFS simulation. This terminal is always actively connected to the SCC operating system. Care must be taken that it is handled properly during a simulation. This is specially true when the centrifuge motion is being controlled.

2.3.2.6.2 Visual Display Terminal

This terminal serves as the I/O device for the Redifon SP-2 Visual Display System. Operation of the visual display system for simulation, diagnostics, calibration, modeling and utility tasks require keyboard entry from this terminal.

2.3.2.6.3 Visual Display Controller

This device controls the Redifon SP-2 visual display system either manually from the front panel, or remotely via the SCC/Visual Display interface (See Section 2.3.5.8).

The visual display controller has the following functions:

o Display System - On/off enables the visual displays to present a scene.

o Data Base Select - Selects the required data base.

o Runway Select - Defines the active runway for light intensity control. Range is 0 through 5.

o Activate - Used in conjunction with "Runway Select" and transfers light intensity control from the previously selected runway to that in "Runway Select".

o Horizon Brightness - Controls horizon brightness in discrete levels. Range is 0 through 5.

o Directional Horizon - Provides a dynamic horizon brightness feature in relation to aircraft heading. Implemented when horizon brightness is 0.

o Light Control - The capability to control the brightness level of up to four types of lights for each runway. Each light type can be varied in brightness level in six steps from 0 to 5.

o Light On/Off Control - On/off selection of up to four types of lights for each runway, e.g., VASI, REIL, Strobe.

o Visibility - Controls the range at which lights and surfaces are visible. 0 to 40 miles in 0.5 mile increments.

o Runway Visible Range (RVR) - Controls the range at which lights and surfaces are visible. RVR is not utilized unless visibility is set to 0.

- o Cloud ceiling - Controls the cloud ceiling relative to runway height. 0 to 9990 ft. in 10 ft. increments.

- o Cloudtop - Controls the cloud top relative to sea level. 0 to 19,000 ft. in 1,000 ft. increments.

- o Cloud Top Illumination - Selects the upper surface of the cloud layer to be illuminated.

- o Ground Fog - Selects ground fog. When selected, visibility applies to the region above the ground fog layer and RVR applies within the ground fog layer.

- o Scud Cloud - Implements random visibility variations in the lower regions of the cloud layer.

- o Ambient illumination - Selects illumination level.

  0 - overcast night
  1 - clear night
  2 - overcast dusk
  3 - clear dusk
  4 - overcast day
  5 - clear day

Switch color logic will be in accordance with the other instructions.

2.3.2.6.4 Data Display Terminal

This display consists of a page oriented CRT which continuously displays required data to be observed during the simulation. The Data Display Terminal is updated every interrupt interval during the run mode. A high speed data communication interface is required to the SCC to provide the data rates this terminal uses. The Data Display Terminal specifications are shown in Table XII.

2.3.2.7 Crewstation Drive Equipment Power and Cooling Requirements

Due to the high concentration of heat producing equipment in the Crewstation Drive Area, additional air conditioning capacity will be needed to cool the room in Bldg 70 where the equipment is located. The estimated BTU/HR LOADS, along with the equipment electrical power requirements are shown in Table XIII.

TABLE XII. DATA DISPLAY TERMINAL SPECIFICATIONS

X-Axis, Y-Axis (Deflection) Amplifiers:

Sensitivity	±2 volts = 13 inches (max. gain)
Position Repeatability	±0.1% of 13 inches
Jitter	0.1% of 13 inches
Input Connectors	
Input Impedance	100 ohms differential
Input Level	±10 volts max.
Rise Time	250 nanosec (10%-90% current for 0.25 inch movement)
Settling Time	10.0 microsec to 0.1% (full 13 inches) 1.5 microsec to 0.1% (4 inches)
Supply Voltages	±40 volts regulated ±35 volts unregulated

Z-Axis (Video) Amplifier:

Sensitivity	0 to 1 volt (1 volt = full on)
Input Impedance	100 ohms, single ended
Input Level	5 volts max.
Rise Time	20 nanosec (10%-90%)
Output Voltage Swing	60 to 0 volts
Supply voltages	+70 volts regulated -40 volts regulated

CRT:

Usable Area	
Maximum Inscribed Square	13 inches by 13 inches
Horiz. Max. Screen Dimension	19 inches
Vert. Max. Screen Dimension	15 inches
Accelerator Voltage	16.5 kilovolts
Focus Voltage	-100 to 400 volts, variable
Resolution	0.020 inch (shrinking raster at screen center)

TABLE XIII. CREW STATION DRIVE AREA UTILITIES REQUIREMENTS

Crew Station Drive Equipment	Power Type	Volts	Amps	Cooling BTU/HR	Comments
Visual Display Processor (Redifon)	1 phase 8500 W	220VAC 240VAC	37	19,000	-two windows -switched breaker box
Cockpit Displays	500 W	120VAC	Data Req'd	Data Req'd	
Simulation Control Computer	1 phase 4226 W 60 Hz	115VAC	37	15,000	-requires separate 100 amp service for isolation
Analog Computer and Control System	3 phase 60 Hz	115VAC	Data Reqd	120,000 to 240,000	

2.3.3 Centrifuge Gondola Crewstation Equipment

The centrifuge gondola crewstation (AREA 5), highlighted in Figure 20, consists of a multipurpose cockpit, a simulated real-world visual display unit, instrumentation, cockpit displays, a head-up display, flight controls, panels, switches, indicators, a buffet system, and a microprocessor controlled crewstation/computer interface system. This section of the report provides detailed specifications and/or functional requirements for each item of equipment utilized in the cockpit crewstation.

The most immediate program which will utilize the multipurpose crewstation is the F-14 Spin Simulation program; therefore, the cockpit panel configuration will be a close replica of the F-14 aircraft. Accommodation shall be provided for the installation of the F-14 aircraft cockpit panel, instrumentation, displays, flight controls, cockpit seat, selected panels, switches, and indicators. The F-14 aircraft cockpit panel is illustrated in Figure 21.

2.3.3.1 Gondola Crewstation Cockpit

The NAVAIRDEVCEN Dynamic Flight Simulator Multipurpose Cockpit design will have the flexibility of being configured into a variety of aircraft. The multipurpose crewstation concept, illustrated in Figure 22, consists of a general cockpit structure and platform, housing a specific cockpit panel and a J Box wiring cockpit/computer interface enclosure as described in reference (n). The cockpit panel assembly, including the front panel, instrumentation, and cockpit/computer interface will be constructed as a drawer, with the capability of being removed and a new cockpit panel assembly, with completely different aircraft features, installed.

The multipurpose crewstation cockpit panel shall maintain as a minimum, the correct MIL Standard down vision, panel width, pilot-eye-to-panel and ejection envelope dimensions. The cockpit panel instrument and display layout shall also closely resemble the specific simulated aircraft. High sustained g requirements imply that the DFS will be used primarily for the simulation of a fixed wing aircraft; however, the simulator should have the capacity to be utilized for certain mission tasks with a helicopter or V/STOL cockpit configuration. The type of aircraft utilized in the Dynamic Flight Simulator will dictate the requirements for instrumentation, flight controls, displays, etc. The cockpit seating configuration will be limited to a single seat because of space limitations in the centrifuge gondola.

The cockput structure shall be constructed with enough flexibility to obtain certain features of the simulated aircraft, such as cockpit width. The pilot's consoles shall be constructed so that the forward and side angles may be varied to conform to the simulated aircraft.

The multipurpose crewstation cockpit panel drawer shall provide enough space to accommodate the cockpit/computer J-Box interface. The J-Box wiring distribution consists of four 20-pin coax AMP connectors and twelve 90-pin Elco connectors.

The multipurpose cockpit crewstation specifications are presented in Table XIV.

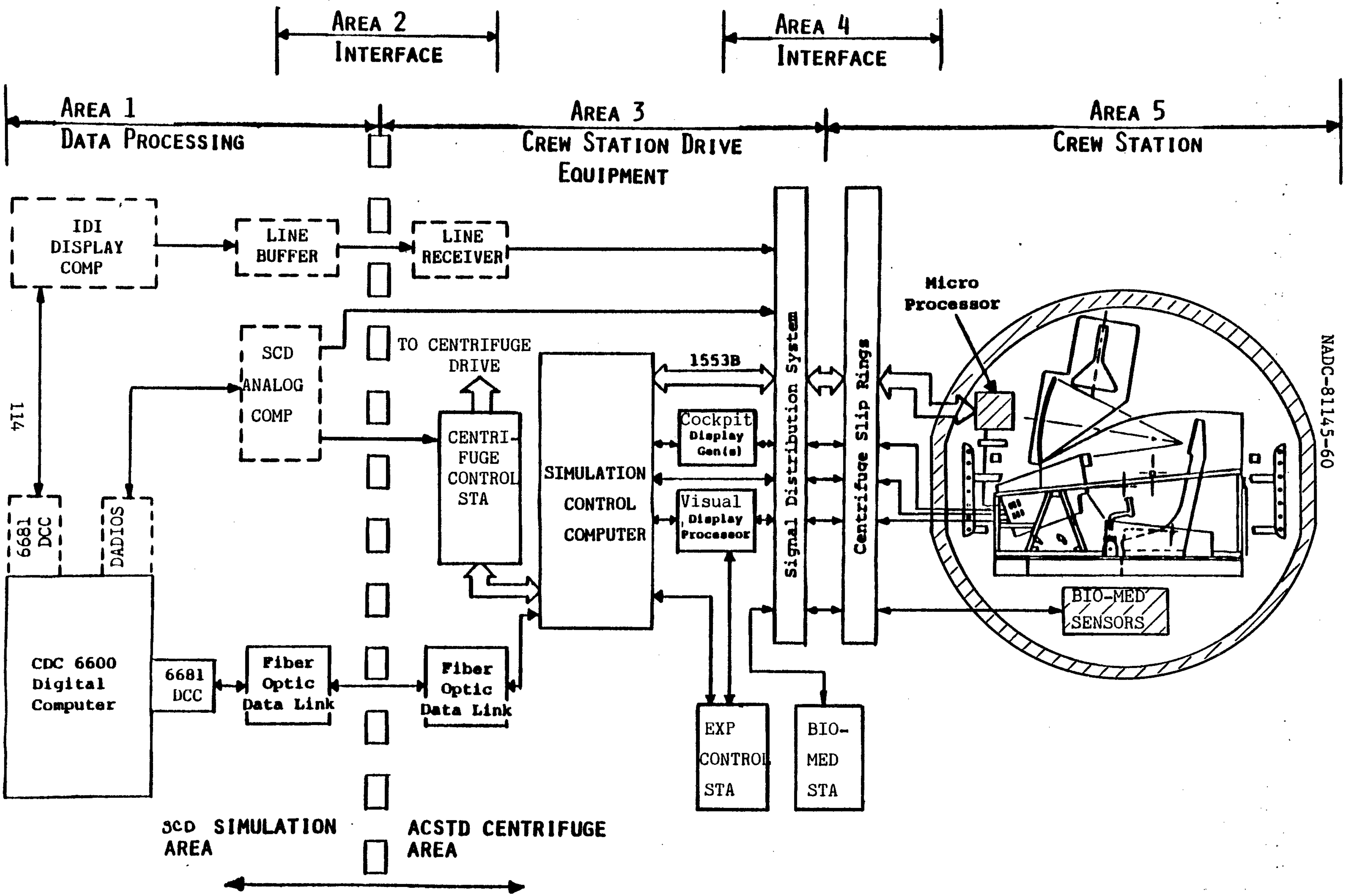


FIGURE 20. DFS CREWSTATION HARDWARE EQUIPMENT (AREA 5)

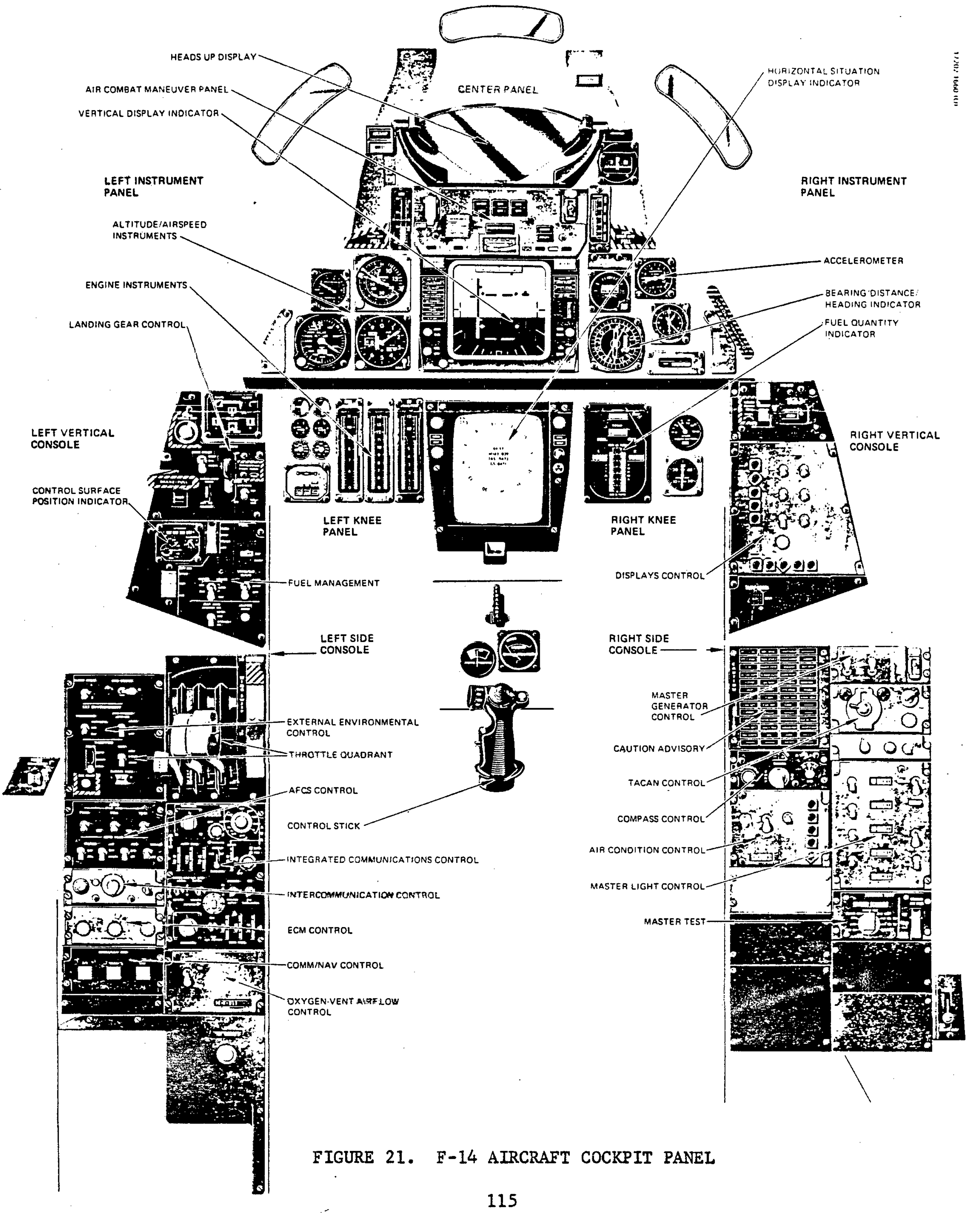


FIGURE 21. F-14 AIRCRAFT COCKPIT PANEL

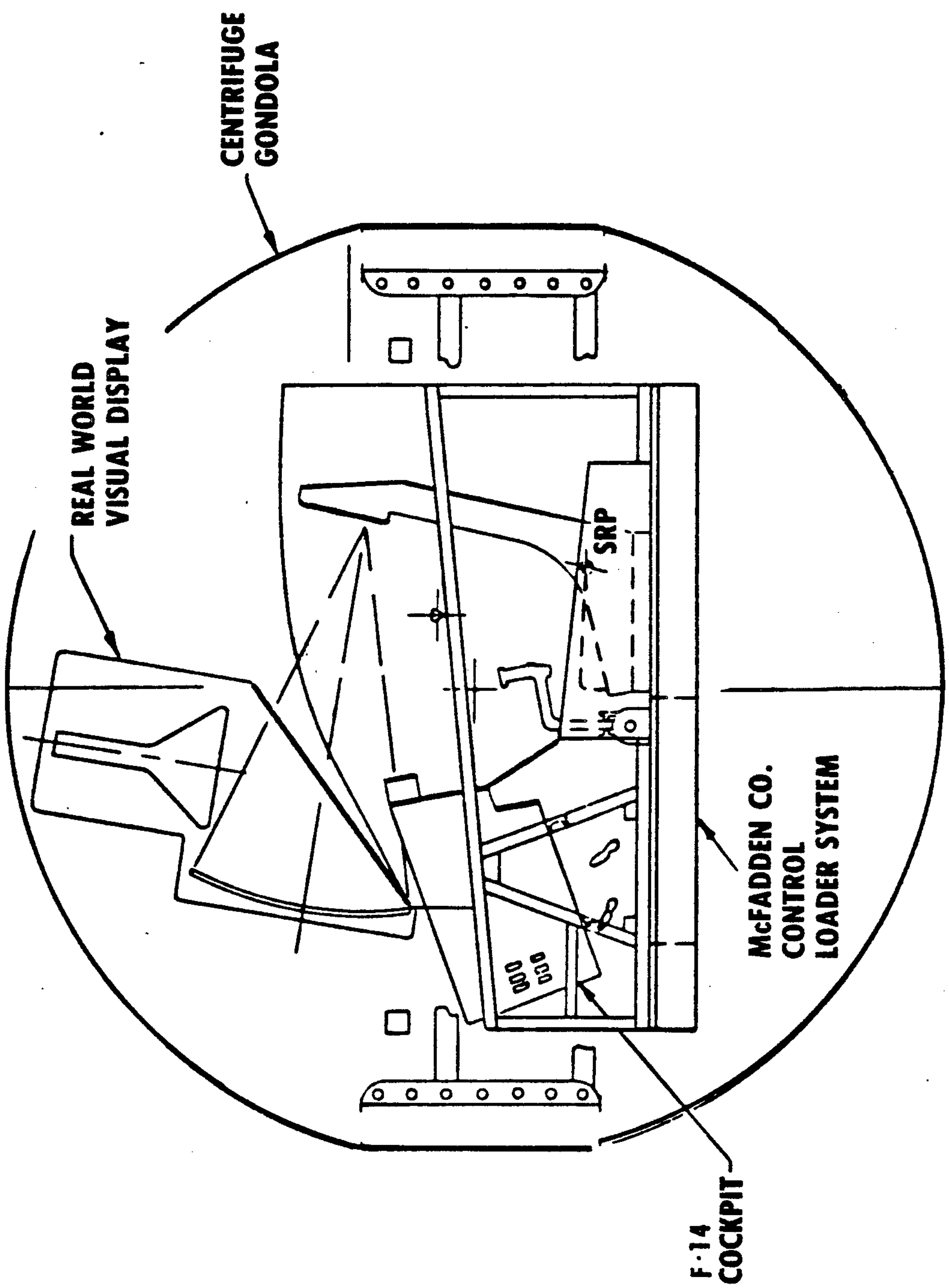


FIGURE 22. F-14 COCKPIT CREWSTATION

TABLE XIV. MULTIPURPOSE COCKPIT CREWSTATION SPECIFICATIONS

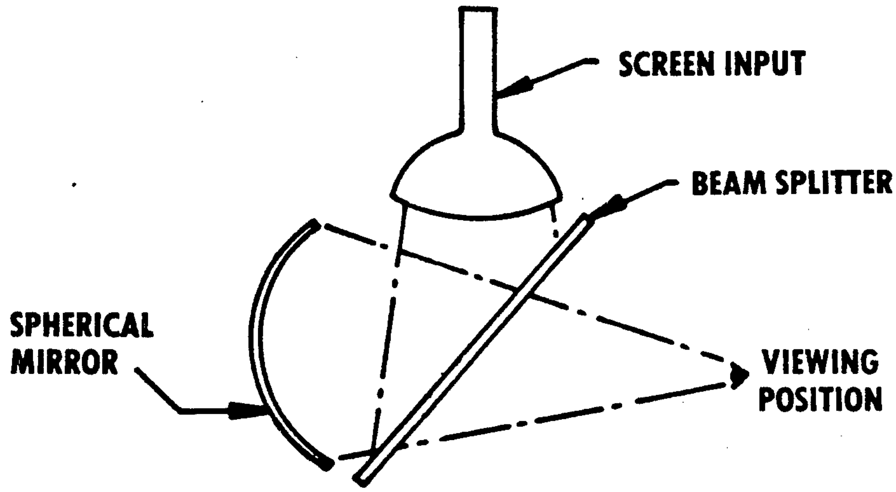
Aircraft:	V/STOL, Helicopter or Fixed Wing
Cockpit Configuration:	Single Seat
Mission Requirements: (Typical)	Take-off and Landing, Weapon Delivery, Target Identification and Acquisition, Survivability and Vulnerability, Flight Performance, Equipment Test and Evaluation, Human Factors Physiological and Environmental Training Familiarization
System Size and Weight:	Compatible with NAVAIRDEVCEN Centrifuge Gondola
Motion:	Cockpit crewstation compatible with centrifuge dynamics (15g in all axis directions)
Fastening of Structural Components	Bolts and Screws
Cockpit Panel Down Vision Angle:	15° 38'
Cockpit Panel Width (Total):	18.5 inches
Pilot Eye to ACM Panel Dimension (min.):	21.5 inches
Ejection Envelope Dimension:	30 inches
Main Cockpit Structure Width:	32.5 inches
Console Forward Angle:	7°
Console Side Angle:	25°
Console to Console Dimension	20 Inches to 28 Inches

2.3.3.2 The Visual Display Unit

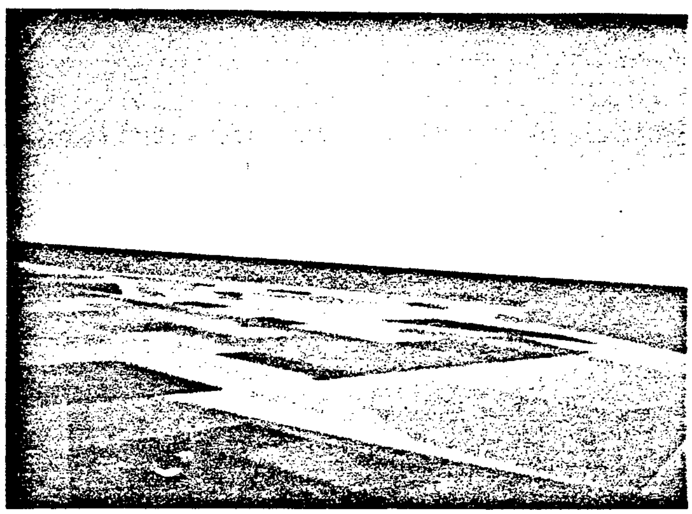
The visual display unit, illustrated in Figure 23, consists of an input shadow mask, 600 raster line cathode ray tube, a beam-splitter, and a 60 inch radius spherical mirror utilized to produce a virtual image, appearing at infinity. This system will present to the pilot a three color, day brightness, real-world virtual image with 512 edges of computer generated image scene detail. The display unit will provide a 48 degree horizontal by 32 degree vertical field-of-view out of the Cockpit's forward window. A raster conversion unit will allow the presentation of the NAVAIRDEVCEN Terrain Model Scene Generator as well as other video transmissions.

The visual display unit requires a power supply located in the gondola to provide the display units required voltages, detailed in section 2.3.3.11.

The specifications for the visual display unit are presented in Table XV. Other visual display system information can be found in Sections 2.3.2.1 and 2.3.2.6.3.



(a) REAL-WORLD VISUAL DISPLAY UNIT



(b) PRESENTATION

FIGURE 23. SP-2 VISUAL DISPLAY UNIT AND PRESENTATION

TABLE XV. Visual Display Unit Specifications

Field of View	48 deg horizontal, 32 deg vertical Each window (forward & side)
Resolution	5 arc min
Brightness	4 ft lamberts (day capability)
Contrast	25 to 1 (day capability)
Viewing Volume	6 in. x 6 in. by 6 in. (min.)
Eye Relief	2 ft. (min.)
Scene Detail	
o Lights (points)	1,000 (day) 5,000 (night/dusk)
o Surface (polygons)	450 (day) 225 (night/dusk)
o Edges	512 (day)
Capability	
o Lights	8 - red, orange, amber, white, blue/ white, pale green, green
o Surfaces	64 combinations of red, green, and blue
Display Type	25 in. high resolution raster shadow mask
Update Rate	40 HZ (day) 30 HZ (night/dusk)
Special Display Effects	Fog, in cloud, scud, ground fog, continuous or directional horizon option
Motion	Display unit compatible with Centrifuge dynamics (15g in all axis direction)
System Size and Weight	Display unit compatible with NAVAIRDEVCEN Centrifuge gondola
Power Requirements	230V AC 60 HZ
Distance Between Components	Display unit will be located within 250 feet of Scene Generator System.
Display Distortion	Less than 5%
Collimation Error	$\pm$ 17 arc mins of convergence and divergence

2.3.3.3 Head-Up Display Unit

The F-14 aircraft Head-Up Display (HUD) provides a combination of real-world cues and flight direction symbology, projected directly on the windshield. The display is focused at infinity, thereby creating the illusion that the symbols are superimposed on the real-world and so the visual cues received from outside the aircraft are not observed. The symbology for the HUD is basically attack oriented, but it also displays attitude, flight situation, and command information. The HUD presentation is generated entirely by calligraphic means. The overall field-of-view of the HUD is 20 degrees. A typical F-14 Head-Up Display presentation is illustrated in Figure 24. The HUD symbology is detailed in reference (c), pages 8-16 to 8-19.

The Head-Up Display specifications utilized in the Dynamic Flight Simulator are presented in Table XVI.

The symbol generation unit, required for the Head-Up Display, the Vertical Display Indicator, and the Horizontal Situation Display, is described in Section 2.3.2.2 of this report.

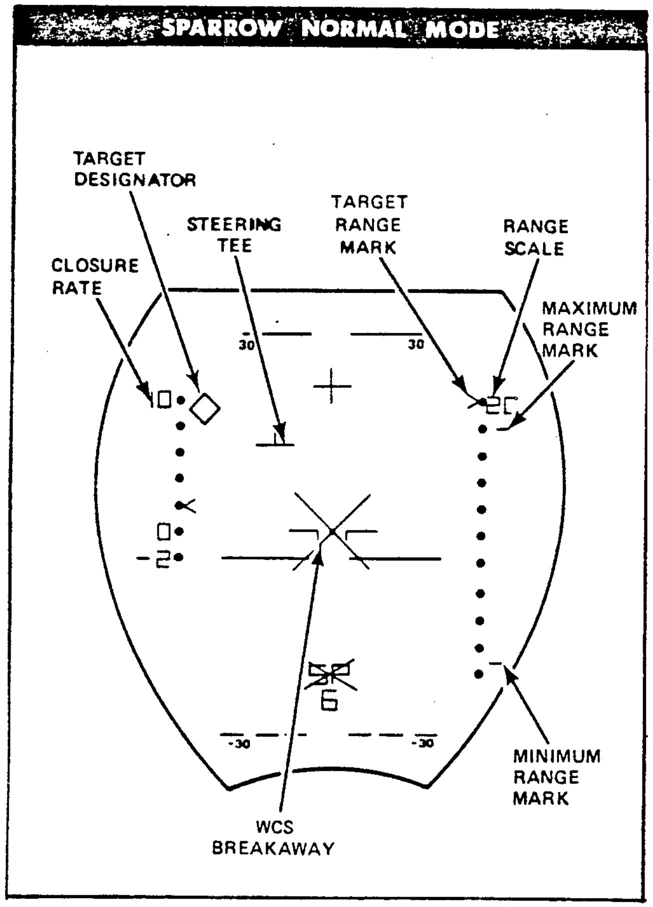


FIGURE 24.

F-14 AIRCRAFT HEAD-UP DISPLAY PRESENTATION

TABLE XVI

Dynamic Flight Simulator Head-Up Display (HUD) Specifications

Field-of-View	20° overall
Instantaneous Field-of-View	15° Azimuth 10° Elevation
Display Screen	Windshield or Combiner Glass
Display Generation Technique	Calligraphic
Weight of Head-Up Display	30 lbs (max)
Power Required	Utilizes standard 115 ac, 60HZ, 115 ac 400HZ, 115/230 ac 30 or 28 V dc
Size of Head-Up Display (not including combiner glass)	6 in. high by 6 in wide by 20 in. long (max)
Head-Up Display modes	Air-to-Air, guns and missiles Air-to-Ground, bombs and missiles Navigation Built-In-Test
Motion	HUD Unit Compatible with centrifuge dynamics (15 g in all axis directions)

2.3.3.4 Cockpit Displays (VDI, HSD)

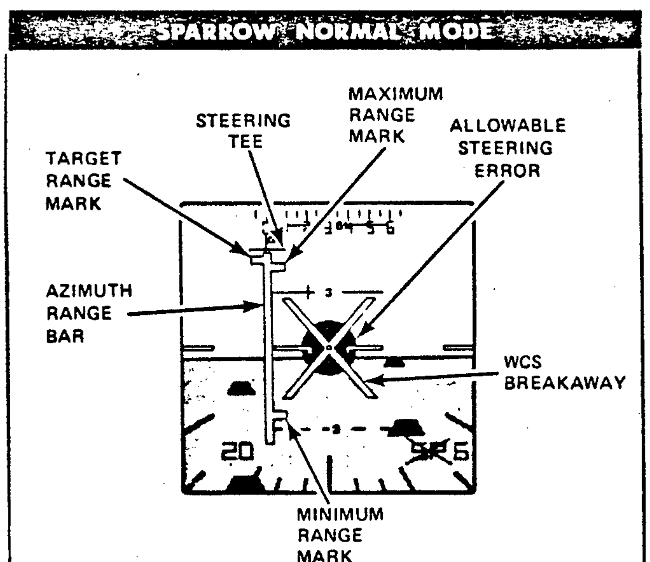
The F-14 Aircraft includes a vertical display indicator and a horizontal situation display. The vertical display indicator (VDI) provides an in the cockpit display of aircraft attitude and navigation to the pilot. A typical F-14 vertical display indicator presentation is illustrated in Figure 25. Attitude information is displayed on the VDI by an aircraft reticle, a horizon line, ground and sky texture and a calligraphic pitch ladder. The aircraft reticle is fixed at the center of the display, and the horizon and pitch ladder moves about it in accordance with the aircraft pitch and roll attitudes. The flight parameters displayed include magnetic heading, D/L commanded airspeed, altitude, vertical velocity. Ground texture elements superimposed on the ground plane simulate both motion and simple perspective. The VDI provides an in-the-cockpit vertical display to the pilot during medium and long-range missile attacks, initiation of visual identification passes, data-link vectoring, automatic carrier landing, aircraft flight attitude, and navigation.

The F-14 aircraft VDI uses a combination of calligraphic or stroke-writing techniques with a raster scan. The 525 line raster scan enables a great deal of symbology to be generated, and the calligraphy adds sharp bright lines where needed for accuracy and high resolution. Steering information and pitch lines are generated calligraphically, for example, stroke writing is performed during the retrace of the raster scan.

The vertical display indicator specifications utilized in the Dynamic Flight Simulator are presented in Table XVII.

The Horizontal Situation Display (HSD) is the pilot's primary navigation display. The HSD is also capable of displaying ECM information as well as repeating the second seat tactical presentation. A number of typical F-14 horizontal display presentations are illustrated in Figure 26. The HSD presents navigation information such as magnetic heading of the aircraft, command heading, command course, TACAN bearing, ADF bearing, data block, and range readout. The data block presents alphanumerics of the aircraft's true airspeed, windspeed, direction, and groundspeed. Range to TACAN station, an RIO inserted destination, or an RIO manually set range is displayed on the HSD range readout. The aircraft heading (a compass rose read against a rubber line) is presented in all display modes.

The horizontal situation display specifications utilized in the Dynamic Flight Simulator are presented in Table XVIII.



NOTE

- MODE CAN ALSO BE ENTERED BY SELECTING ACM
- D/L COMMANDS CAN BE DISPLAYED IN THIS MODE
- PITCH LINES, AND HORIZON LINE CAN BE DECLUTTERED ON HUD

FIGURE 25.
F-14 AIRCRAFT VERTICAL
DISPLAY PRESENTATION

TABLE XVII

Dynamic Flight Simulator Vertical Display Indicator (VDI) Specifications

Display screen size	5 in. wide by 5 in. high
Resolution	5 ARC MIN
Brightness	5 FT LAM
Contrast	25 to 1
Display Presentation	Hybrid (Stroke and raster written)
Writing speed	1.5 microsec/inch
Refresh rate	80HZ Stroke 40-80HZ Raster
Phosphor color	Green or Chromatic
Linearity	3%
Allowable distortion (percent)	5%
Positional resolution	less than .002 in.
Bandwidth	5MHZ (min)
Display Weight	25 lbs (max)
Power requirement	Utilizes standard 115Vac, 60HZ, 115Vac, 400HZ, 115/230Vac, 30 or 28Vdc
Size of unit	6 in. wide by 6 in. high by 16 in. deep (max)
Motion	Display Unit Compatible with centrifuge dynamics (15 g in all axis directions)

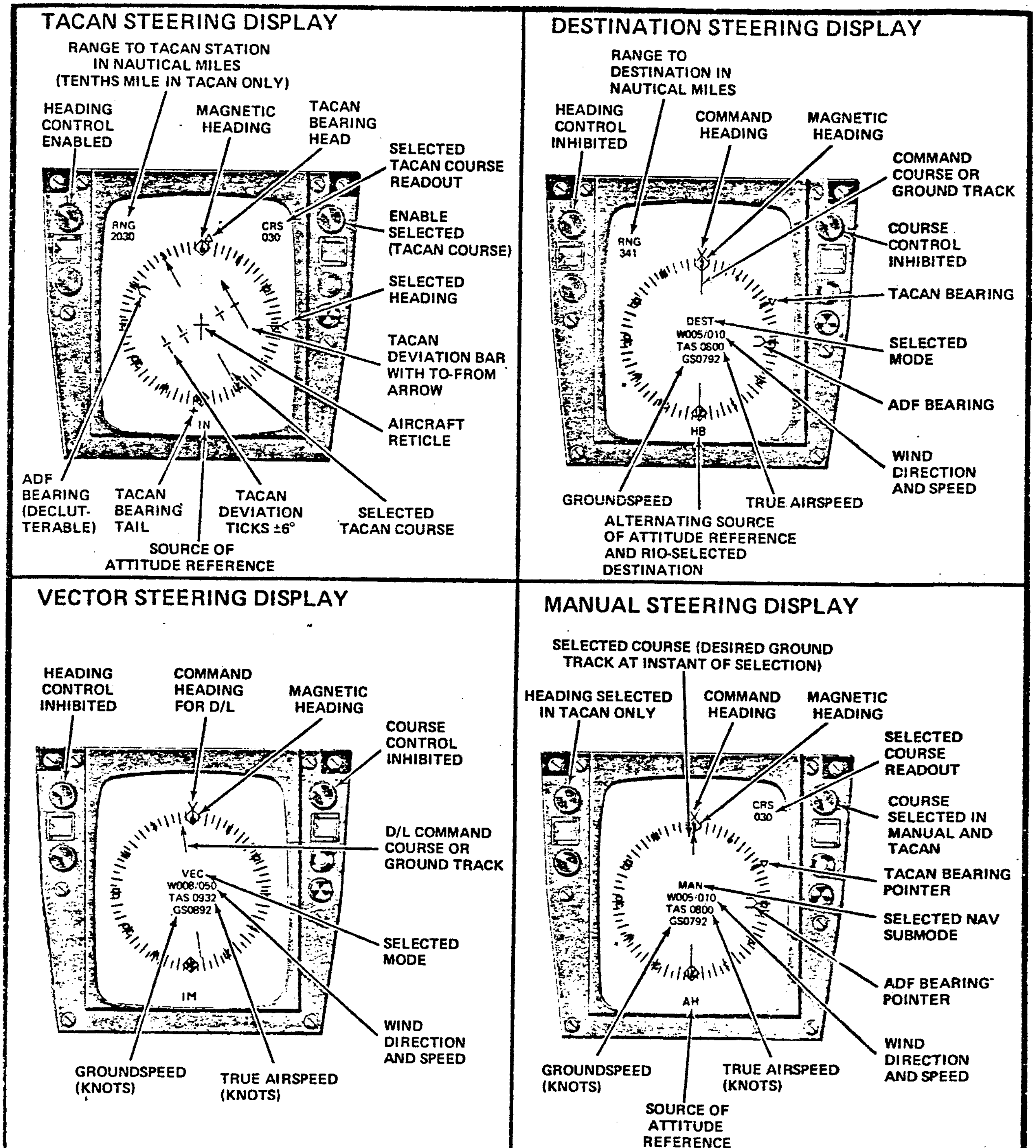


FIGURE 26.

F-14 AIRCRAFT HORIZONTAL

DISPLAY PRESENTATION

TABLE XVIII

Dynamic Flight Simulator Horizontal Situation Display Specifications

Display screen size	5 in. wide by 6 1/2 in. high
Resolution	5 arc min
Brightness	5 ft. lam
Contrast	25 to 1
Display Presentation	Hybrid (Stroke as raster written)
Writing speed	1.5 microsec/inch
Refresh rate	80HZ Stroke 40-80HZ Raster
Phosphor color	Green or Chromatic
Linearity	3%
Allowable distortion	5%
Positional resolution	less than .002 in.
Bandwidth	5MHZ
Display Weight	30 lbs. (max)
Power requirement	Utilizes standard 115 ac, 60HZ, 115 ac 400 HZ, 115/230 ac 30 or 28 V dc
Size of unit	6 in. wide by 7.5 in. high by 16 in. deep (max)
Motion	Display Unit Compatible with centrifuge dynamics (15 g in all axis directions)

2.3.3.5 Stick/Rudder Control Loader System

The cockpit stick/rudder control loader system, Illustrated in Figures 27 and 28, will provide realistic feel simulation, smooth response at low spring gradients, fail safe circuitry, low friction bearings, and will accept electrical analog force commands. The stick/rudder control loader system will provide the following capabilities:

- Forward and aft stops
- Deadband
- Breakout
- Damping
- Velocity Limit
- Friction
- Force Balance
- Forward and Aft Trim Limit
- Trim Rate
- Position Bias

These capabilities will be applied to the roll axis, pitch axis, and rudders.

The artificial feel force characteristics should have the capability of being dialed in quickly and easily to facilitate fast changeover from the simulation of one aircraft to another in a universal cockpit simulator.

The Stick/Rudder Control Loader System Specifications are presented in Table XIX.

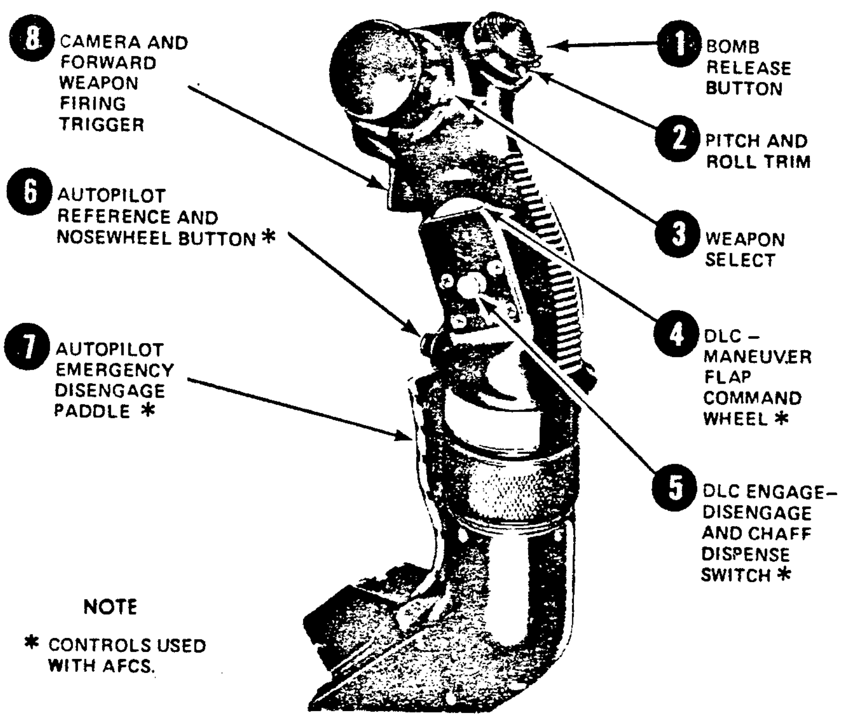


FIGURE 27. STICK CONTROL LOADER SYSTEM

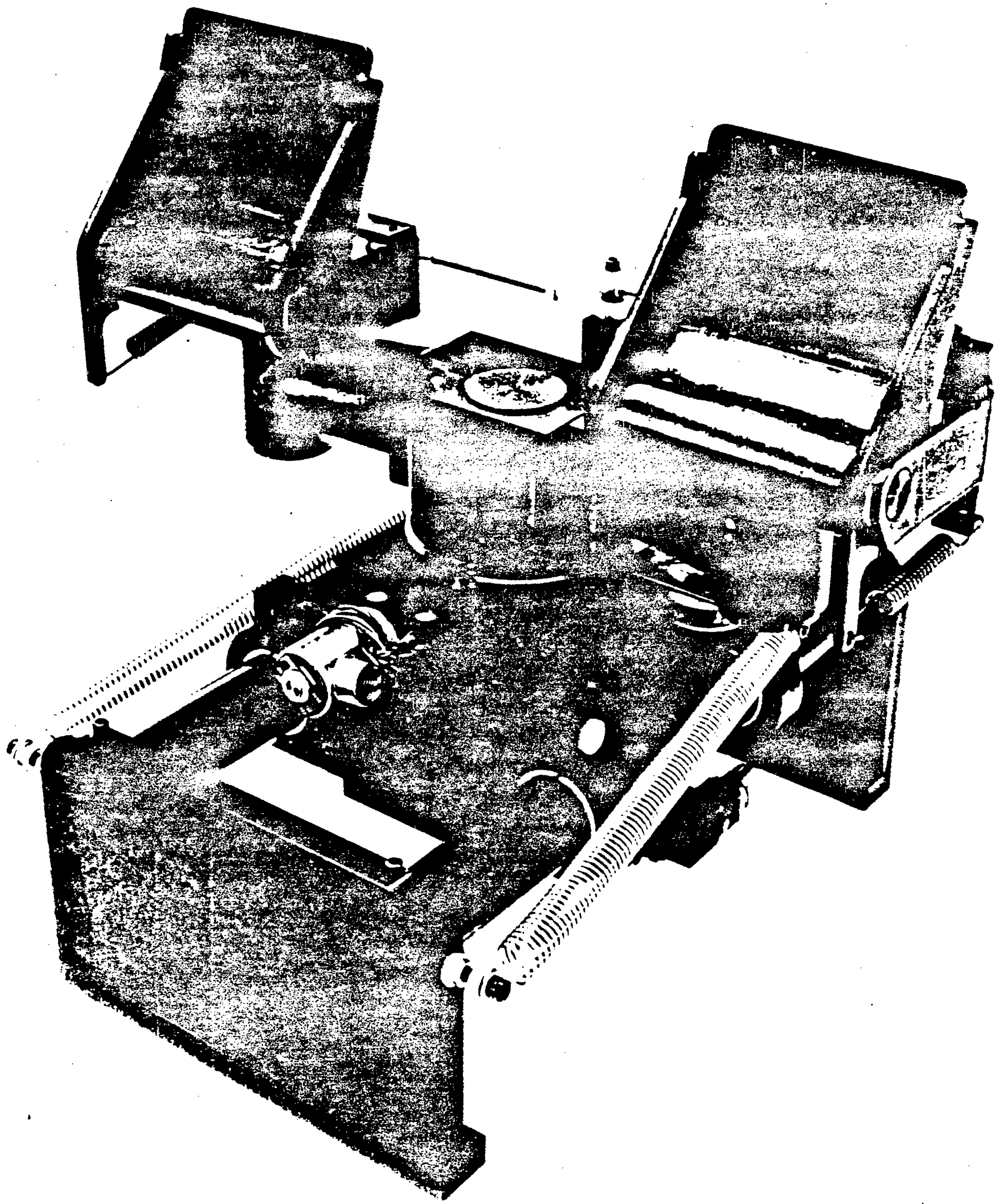


FIGURE 28. RUDDER CONTROL LOADER SYSTEM

TABLE XIX

STICK/RUDDER CONTROL LOADER SYSTEM SPECIFICATIONS

FUNCTION	UNITS	PEDALS	STICK PITCH	STICK ROLL
Control Force (max)	lbs	200	100	100
Control Travel (max)	in	±3.25	+5, -7	±7
Control Velocity (max)	in/sec	50	50	50
Threshold (max) (force loop)	lbs	0.2	0.1	0.1
Response (min freq of force loop)	Hz	50	50	50
Force vs. Position Slope (max additive, electrical)	lbs/in	200	200	200
LINEAR VARIABLE FUNCTIONS				
Spring Gradient	lbs/in	0-75	0-75	0-75
Damping (nominal)	$\frac{\text{lbs}}{\text{in/sec}}$	0-3.0	0-0.5	0-0.5
NON-LINEAR VARIABLE FUNCTIONS				
Breakout (preload)	lbs	0-25	0-25	0-20
Travel Limits (Stops)	in	±1/2 to F.S.	±1/2 to F.S.	±1/2 to F.S
Deadband (Backlash)	in	0-2	0-2	0-2
Coulomb Friction	lbs	0-15	0-15	0-15
Trim Rate	in/sec	0.1 to 1	0.1 to 1	0.1 to 1

Page 1 of 2

Mission Requirements (Typical)	Survivability and vulnerability, Flight Performance, Equipment test and evaluation, Human factors, Physiological and environmental training/ familiarization, Take-off and landing, Weapon delivery, Target identification and acquisition
Cockpit Configuration	Single Seat
Aircraft	Fixed Wing, V/STOL
System Size and Weight	Flight Controls compatible with NAVAIRDEVCEN Multipurpose Cockpit Crewstation
Motion	Flight Controls compatible with centrifuge dynamics (15g's in all axis directions)
Power Requirements	Stick Control Loader System electronic power requirements and drive signals can be obtained from the power available in the centrifuge J-Box. The Dynamic Flight Simulator J-Box is described in section 2.3.3.10. An ample number of input (to the J-Box) connectors will be set aside for this purpose. If additional electical lines are required to pass separately through the centrifuge slip rings, these lines must be compatible with the Gondola Slip Ring Wiring complement described in Section 2.1.5.
Distance between Components	Stick control Loader system and electronics are located inside centrifuge gondola. Selected control electronics located 250 ft. from gondola. CDC 6600 Computer located 2500 ft. from gondola. Hydraulic pump located 75 ft. from gondola.

2.3.3.6 Throttle System

The F-14 aircraft throttle system, illustrated in Figure 29, consists of a MACH lever which provides a mechanical input to the main fuel control, a wing sweep level arm providing wing sweep angle variations between 20 - 68 degrees, an emergency wing sweep handle, item 1 in Figure 29, and a flap lever arm providing augmented lift during takeoff, landing, or maneuvering flight. The F-14 aircraft throttle is provided with a four position wing sweep mode switch (auto, bomb, aft, fwd), item 2 in Figure 29, a two position speed brake switch (extension, retracted), item 3, and two position communication switch (UHF, ICS) item 4.

2.3.3.7 Instrumentation

The dynamic flight simulator instrumentation depends on the particular aircraft required for the experiment task. The instrumentation normally required includes the following indicators:

Airspeed
Rate of Climb
Radar Altimeter
Barometric Altimeter
Altitude
Bearing, Distance, Heading

Depending on the type of aircraft to be simulated, additional instrumentation could include the following indicators:

Accelerometer
Angle of Attack
Turn and Slip
Engine

Most simulated cockpit instruments can be commercially purchased as an exact replica of the aircraft instrument with a simple variable dc voltage input simulating the actual aircraft sensor input. The only problem with simulated cockpit instruments is that they often do not have the lags, errors, and noise characteristics of the real-world, especially for displays of airspeed, rate of climb, or angle of attack.

Since the initial program planned for the Dynamic Flight Simulator will involve the F-14 aircraft the active instrumentation required will be those designated necessary by several F-14 pilots, other fixed wing pilots, and human factors engineers. These instruments illustrated in Section 2.3.3.12 are:

Angle of Attack Indicator
Wing Sweep Indicator
Attitude Indicator
Bearing/Distance/Heading Indicator
Accelerometer Indicator
Radar Altimeter
Airspeed Indicator

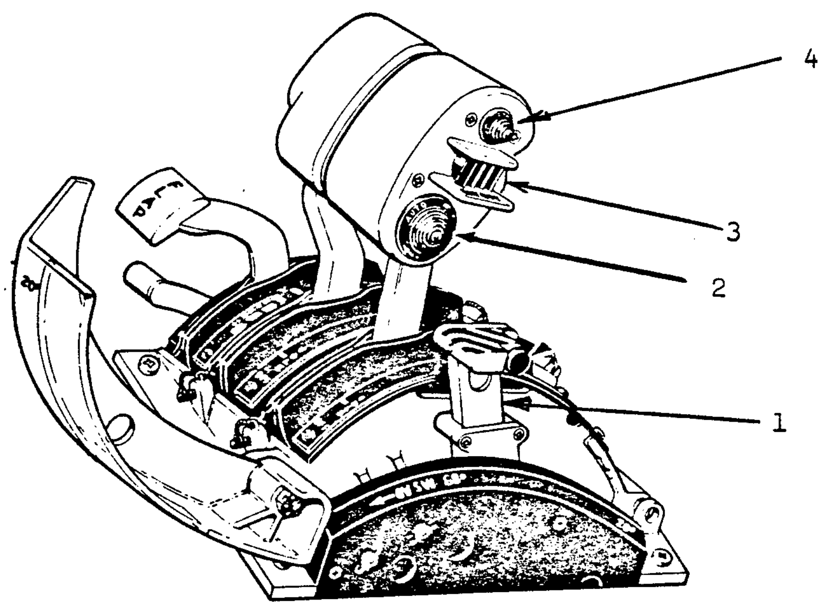


FIGURE 29.
F-14 AIRCRAFT THROTTLE (8)

Barometric Altitude Indicator
Rate of Climb Indicator
Turn and Slip Indicator
Dual RPM Indicator
Dual Turbine Inlet Temperature Indicator
Dual Fuel Flow Indicator

2.3.3.8 Panels, Switches, and Indicator Lights

The cockpit panels, switches, and indicator lights will be an exact replica of an F-14 aircraft. The aircraft panels designated to be active include:

- o Auto Flight Control
- o Auto Throttle Control
- o Flaps, Slats, and Speed Brake
- o Fuel Management/Spoilers
- o Air Combat Maneuvering Control
- o Display
- o Caution
- o Landing/Emergency Stores Jettison
- o Landing Gear Handle

These panels are illustrated in Section 2.3.3.12. Dummy panels for the remaining aircraft panels will also be provided.

2.3.3.9 Bio-Medical Sensors

Bio-medical monitoring requires sensors to be placed on the subject pilot and requires the proper instrumentation to convert the sensor output into a suitable electrical equivalent for transmission from the subject pilot station. The standard sensors and instrumentation include the following:

- a low light level video camera

- two sets of three lead ECG sensors with separate isolated ECG amplifiers

- a blood pressure cuff with an automatic pressure monitor

- ultrasonic doppler sensor with its controller and conditioner

2.3.3.10 Gondola Crewstation Microprocessor/J-Box Equipment

The multipurpose cockpit crewstation, located inside the centrifuge gondola, will be driven by various processors and computers external to the centrifuge gondola. The I/O signals to these computers will be controlled by a microprocessor located within the gondola. As previously described in Section 2.1.5, the NAVAIRDEVCEN centrifuge gondola is limited in the wiring complement through the system's slip rings and therefore mutliplexing

techniques must be utilized to facilitate the wiring required to drive the crewstation equipment.

The gondola crewstation microprocessor control system, illustrated in Figure 30, consists of a J-Box integrated into the rear of the cockpit panel drawer structure, a flight control electronic processor, a Sesco Company SECS 80 Microprocessor and peripheral equipment. The SECS 80 microprocessor will control the indiscretes, outdiscretes, D/A and A/D signals transmitted through the centrifuge slip rings via a 1553B Bus. The J-Box distribution system integrated into the rear of the cockpit panel structure is illustrated in Figure 31. The J-Box distribution consists of four 20-pin coax AMP connectors and twelve 90-pin Elco connectors.

- o Sixteen coax lines are utilized to drive the real-world visual display unit (one unit), the HSD, the VDI, the HUD, and the medical monitor TV camera.
- o Sixteen power lines are utilized to provide the necessary cockpit equipment power inputs. Eight 80-pin Elco connectors are used for the cockpit power distribution interface. Thirty Elco pins are jumpered together, on each connector, to provide the necessary number of input lines.
- o A single 75 ohm Coaxial line will be utilized as a 1553B Bus circuit to transfer indiscrete, outdiscrete, D/A and A/D signals from the Simulation Control Computer to the SECS-80 Microprocessor. Signal conditioning circuits will be utilized where necessary.

Sesco's Severe Environment Computer System, designated SECS 80/10A, is a ruggedized single board microcomputer which takes full advantage of LSI technology. Sesco's 80/10A is the severe environment counter-part to the commercial Intel 80/10A single board computer (SBC) and is compatible with development system software available from Intel. The severe environment features include high and low temperature, high vibration, high shock, and corrosive resistance required in the NAVAIRDEVCEN Centrifuge environment. The SECS 80/10A features include:

- o 48 Programmable Parallel I/O Lines
- o Serial communication
- o 6 Interrupt Request Lines
- o Bus Drivers for memory and I/O Expansion

The DFS Microprocessor Specifications are presented in Table X.

In order to activate the F-14 instruments shown in section 2.3.3.12, the DFS microprocessor will be required to control 20 D/A circuits, 7 A/D circuits, 30 indiscretes (switch closures) and 25 outdiscretes (lamp drivers or meter movement drivers).

The SECS-80 microprocessor will include a full ATR chassis (SECS-80/ATR 2), five D/A converter cards (SECS-80/724), and A/D converter card (SECS-80/732), a programmable I/O expansion card (SECS-80/519), a 1553 Bus interface card (SECS-80/1553), a 16K RAM card (SECS-80/116), an 8 bit microprocessor card (SECS-80/10A), and two 115 Vdc power supplies (SECS-80/PS).

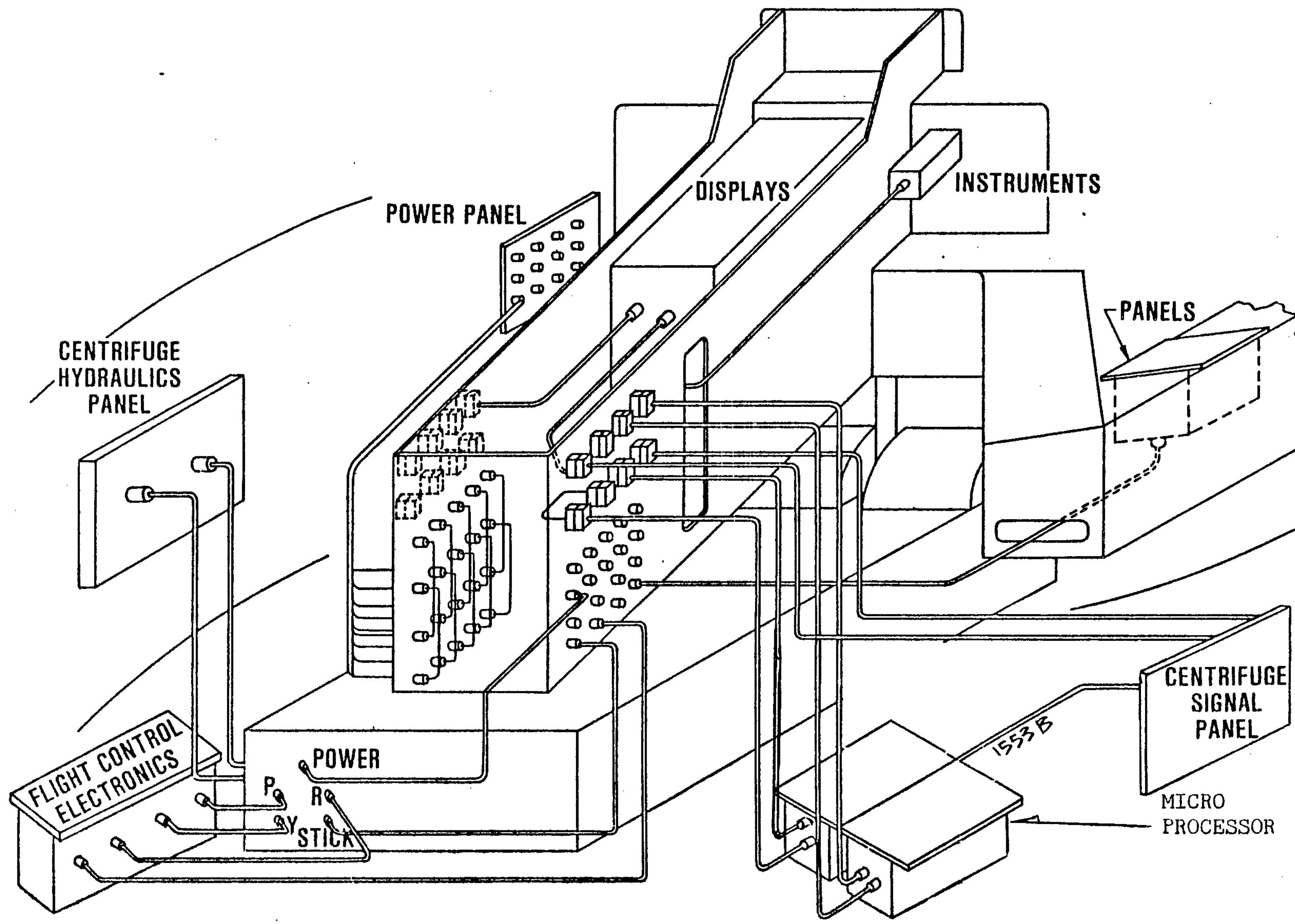


FIGURE 30. DYNAMIC FLIGHT SIMULATOR COCKPIT/COMPUTER WIRING DISTRIBUTION

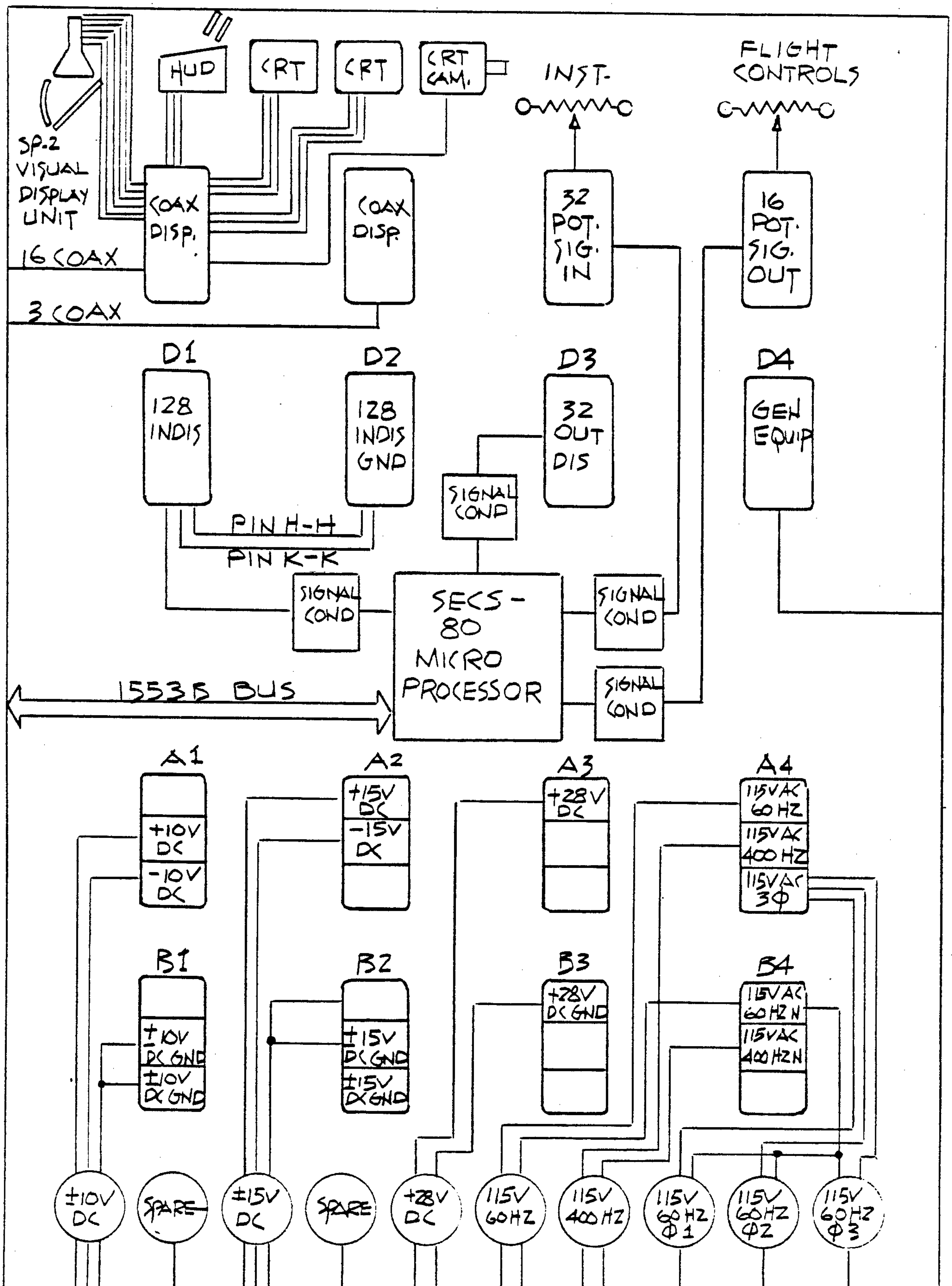


FIGURE 31. DFS CENTRIFUGE GONDOLA WIRING SCHEME

TABLE XX. DFS MICROPROCESSOR SPECIFICATIONS

WORD SIZE

Instruction: 8, 16, or 24 bits

Data: 8 bits

CYCLE TIME

Basic Instruction Cycle: 1.95 microseconds

Note: Basic instruction cycle is defined as the fastest instruction (i.e. four clock cycles)

MEMORY CAPACITY

On-Board ROM/PROM up to 8K bytes

On-Board RAM: 1K bytes

Off-Board Expansion: Up to 65,536 bytes using user specified combinations or RAM, ROM and PROM

Note: ROM/PROM may be added in 1K byte increments.

SERIAL COMMUNICATIONS CHARACTERISTICS

Synchronous:

5-7 bit characters
Internal or external character synchronization
Automatic Sync Insertion

Asynchronous:

5-8 bit characters
Break character generation
1, 1 1/2 or 2 stop bits
False start bit detectors

INTERRUPTS

Single-level with on-board logic that automatically vectors processor to location 38_{16} using RESTART 7 instruction.

Interrupt requests may originate from user specified I/O, the programmable peripheral interface, or USART.

Page 1 of 2

INTERFACES

Bus: All signals TTL compatible

Parallel I/O: All signals TTL compabile

Serial I/O: RS232C, or a 20 mil current loop TTY interface (jumper selectable)

Interrupt Requests: All TTL compatible (active low)

SYSTEM CLOCK

2.048 MHz $\pm$0.1%

PHYSICAL CHARACTERISTCS

Width: 9 in. (22.86 cm) Depth: 0.50 in (1.27 cm)

Height: 6 in. (15.24 cm) Weight: 18 oz. (484.4 gm)

ELECTRICAL CHARACTERISTICS

DC Power:	without PROM	with PROM
+ 5V $\pm$5%	2.9A max	4.0A
+12V $\pm$5%	140mA max	400mA
- 5V $\pm$5%	2mA max	200mA
-12V $\pm$5%	175mA max	175mA

ENVIRONMENTAL

Operating Temperature:	-55°C to +85°C
Operating Vibration:	5g; 5Hz to 2K Hz
Operating Shock:	15g; 11 milliseconds
Operating Humidity:	0 to 95% with condensation
Operating Altitude:	Sea level to 70,000 feet

2.3.3.11 Gondola Crewstation Power, Cooling & Weight Requirements

The equipment located within the centrifuge gondola crewstation will require an assortment of electrical power voltages. Table XXI details a list of the equipment and the power requirements. To satisfy the various voltage requirements, selected power supplies will be located within the centrifuge gondola with some equipment providing its own internal power conversion. Table XXI also details the watts generated and BTU/HR heat dissipation required for each hardware item located in the gondola. A review of general air conditioning conversions is presented in Table XXII.

The centrifuge gondola is limited in the amount of weight that can be located in the gondola. Table XXIII details a list of the equipment and its estimated weight.

TABLE XXI. DFS CENTRIFUGE
GONDOLA CREWSTATION POWER REQUIREMENTS

EQUIPMENT DESCRIPTION	VOLTAGE REQUIRED	AMPS REQUIRED	WATTS GENERATED	BTU/HR DISSIPATION REQUIRED
1. SP-2 VISUAL DISPLAY UNIT (2 REQ'D) & POWER SUPPLY (2 REQ'D)	+600V.D.C ±120V.D.C ±5V.D.C. 220VAC 60HZ	11a (MAX) per unit	1466 Watts per unit	5000 BTU/HR per display
2. HEAD UP DISPLAY UNIT				
3. COCKPIT DISPLAY	115VAC 400HZ	1.5a	180 watts per unit	614 BTU/HR per Unit
4. STICK CONTROL LOADER UNIT	±10V.D.C. ±15V.D.C 115 VAC 60HZ	1 AMP per Axis	345 watts	1170 BTU/HR
5. THROTTLE UNIT	±10V.D.C 28V.D.C	Data Req'd	Data Req'd	Data Req'd
6. MALWIN INSTRUMENTATION	±10V.D.C ±15V.D.C 28V.D.C 5V.D.C	15MA per Unit	20 Watts Total	68 BTU/HR
7. PANELS, SWITCHES & INDICATORS	28V.D.C	Data Req'd	Data Req'd	Data Req'd
8. BIO MEDICAL SENSORS				
9. SECS 80 MICRO PROCESSOR & POWER SUPPLY	±5V.D.C ±12V.D.C +28V.D.C or 115VAC 60HZ	400 MA (MAX) 14 AMP @ 5V.D.C (MAX)	4.8 Watts 70 Watts	16.4 BTU/HR 240 BTU/HR
10. SECS 80/1553B INTERFACE	5V.D.C ±12V.D.C (FROM SECS 80)	3A (AVE)	37 Watts	126 BTU/HR

TABLE XXII

AIR CONDITIONING CONVERSION FACTORS

1 BTU/sec =	1055 watts
1 BTU/hr =	.2930 watts
6000 BTU/hr =	1758 watts
12000 BTU/hr =	1 TON AIR COND
1 watt =	3.41 BTU/hr

TABLE XXIII. DFS CENTRIFUGE

GONDOLA CREWSTATION EQUIPMENT WEIGHT REQUIREMENTS

EQUIPMENT DESCRIPTION	EQUIPMENT WEIGHT LBS.
1. COCKPIT SHELL	600 LBS
2. CREWMAN	200 LBS
3. SP2 VISUAL DISPLAY UNIT (2 REQ'D & POWER SUPPLY (2 REQ'D)	150 LBS PER UNIT 100 LBS PER UNIT
4. HEAD UP DISPLAY	30 LBS (MAX)
5. COCKPIT DISPLAY UNIT (2 REQ'D)	25 LBS PER UNIT
6. STICK CONTROL LOADER UNIT & ELECTRONICS	175 LBS
7. THROTTLE UNIT	10 LBS (MAX)
8. MALWIN INSTRUMENTATION	10 LBS (MAX)
9. PANELS SWITCHES AND INDICATORS	10 LBS (MAX)
10. SECS 80 MICROPROCESSOR	30 LBS
11. J-BOX INTERFACE	25 LBS
12. COCKPIT BUFFET SYSTEM	10 LBS
13. EQUIPMENT MOUNTING STRUCTURES	
. COCKPIT SHELL	50 LBS
. VISUAL DISPLAY	30 LBS (PER UNIT)
. DISPLAY POWER SUPPLY . STICK ELECTRONICS . SECS 80 MICROPROCESSOR . J-BOX SIGNAL CONDITION BOXES	30 LBS
. COCKPIT BUFFET SYSTEM	10 LBS
TOTAL	1800 LBS

2.3.3.12 Gondola Crewstation F-14 Cockpit Equipment Signal/Range Data

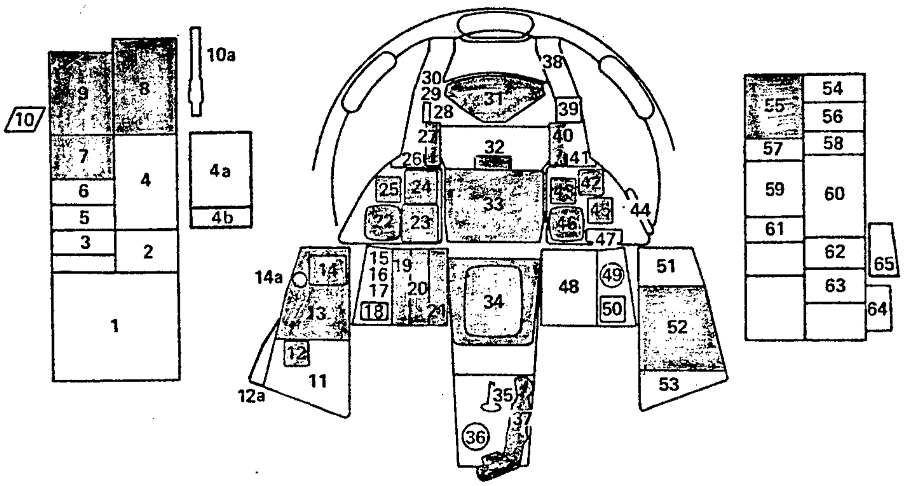
The Dynamic Flight Simulator Crewstation F-14 instrumentation, flight controls, panels, switches, and indicators are driven with servo potentiometer (DA) or outdiscrete (lamp driver) signals, or provide the computer with servo potentiometer (AD) or indiscrete (switch) signals. The potentiometer signals will be a variable $\pm$ 10V.D.C. signal, the indiscrete signal will be a ground, and the outdiscrete signal will be +28V.D.C. This section of the report will provide the complete complement of active signals and the required voltage/range data for the F-14 Spin Simulation.

The F-14 instrumentation, displays, panel switches, and indicators that are to be active are illustrated in Figure 32. Full scale drawings of each active item, numbered according to Figure 32, are presented in Figures 33 to 44. The cockpit display data is presented in Table XXIV; the instrumentation scale/voltage range data is presented in Table XXV; the flight control scale/voltage range and indiscrete signal data is presented in Table XXVI; and the panels, switches, and indicators indiscrete and outdiscrete signal data is presented in Table XXVII.

The instrument data tables, XXIV through XXVII, also contain information on the priority of each instrument for the F-14 Spin Simulation experiment versus other types of experiments which may be performed at a later date. The priority of each instrument 1 through 4, directly reflects the views of the experienced pilots who were interviewed as described in Section 1.6.1. These priorities are:

(1) Instrument needed for normal flight simulation
(2) Instrument needed for Spin Simulation
(3) Instrument may be needed for future experiments, not necessarily involving spin simulation
(4) Instrument not required.

Based on these priorities, the last four columns in the tables indicate whether the instrument will be wired to the J-Box, connected to the Gondola Crewstation microprocessor, modeled in the aero package, or programmed in the software.



LEFT SIDE CONSOLE

1. G VALVE PUSHBUTTON
2. OXYGEN-VENT AIRFLOW CONTROL PANEL
3. COMM/NAV COMMAND CONTROL PANEL
4. INTEGRATED CONTROL PANEL

4a UHF (AN/ARC 159)
4b UHF COMM SELECT PANEL

5. TONE VOLUME CONTROL PANEL
6. ICS CONTROL PANEL
7. AFCS CONTROL PANEL
8. THROTTLE QUADRANT
9. INLET RAMPS/THROTTLE CONTROL PANEL
10. TARGET DESIGNATE SWITCH

10a.HYDRAULIC HAND PUMP

LEFT VERTICAL CONSOLE

11. FUEL MANAGEMENT PANEL
12. CONTROL SURFACE POSITION INDICATOR

12a LAUNCH BAR ABORT PANEL

13. LANDING GEAR CONTROL PANEL
14. WHEELS-FLAPS POSITION INDICATOR

14a.EMER STORES JETTISON BUTTON

LEFT KNEE PANEL

15. ENGINE PRESSURE RATIO INDICATOR
16. EXHAUST NOZZLE POSITION INDICATOR
17. OIL PRESSURE INDICATOR
18. HYDRAULIC PRESSURE INDICATOR
19. ELECTRICAL TACHOMETER INDICATOR (RPM)
20. THERMOCOUPLE TEMPERATURE INDICATOR (TIT)
21. RATE OF FLOW INDICATOR (FF)

LEFT INSTRUMENT PANEL

22. SERVOPNEUMATIC ALTIMETER
23. RADAR ALTIMETER
24. AIRSPEED MACH INDICATOR
25. VERTICAL VELOCITY INDICATOR
26. LEFT ENGINE FUEL SHUT OFF HANDLE
27. ANGLE-OF-ATTACK INDICATOR

LEFT FRONT WINDSHIELD FRAME

28. APPROACH INDEXER
29. WHEELS WARNING LIGHT

29a. BRAKES WARNING LIGHT

30. ACLS/AP CAUTION LIGHT

30a. NWS ENGA CAUTION LIGHT

CENTER PANEL

31. HEADS UP DISPLAY
32. AIR COMBAT MANEUVER PANEL
33. VERTICAL DISPLAY INDICATOR (VDI)
34. HORIZONTAL SITUATION DISPLAY INDICATOR (HSI)
35. PEDAL ADJUST HANDLE
36. BRAKE PRESSURE INDICATOR
37. CONTROL STICK

RIGHT FRONT WINDSHIELD FRAME

38. ECM WARNING LIGHTS
39. STANDBY COMPASS

RIGHT INSTRUMENT PANEL

40. WING SWEEP INDICATOR
41. RIGHT ENGINE FUEL SHUT OFF HANDLE
42. ACCELEROMETER
43. STANDBY ATTITUDE INDICATOR
44. CANOPY JETTISON HANDLE
45. CLOCK
46. BEARING DISTANCE HEADING INDICATOR (BDHI)
47. UHF REMOTE INDICATOR

RIGHT KNEE PANEL

48. FUEL QUANTITY INDICATOR
49. LIQUID OXYGEN QUANTITY INDICATOR
50. CABIN PRESSURE ALTIMETER

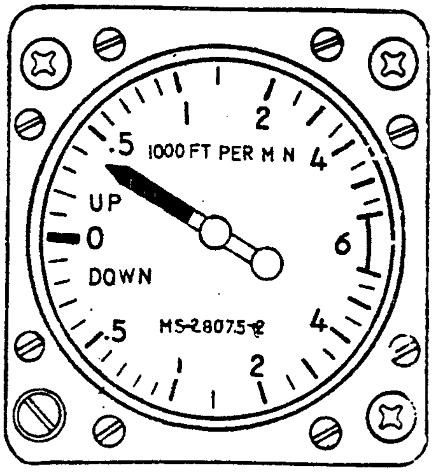
RIGHT VERTICAL CONSOLE

51. ARRESTING HOOK PANEL
52. DISPLAYS CONTROL PANEL
53. ELEVATION LEAD PANEL

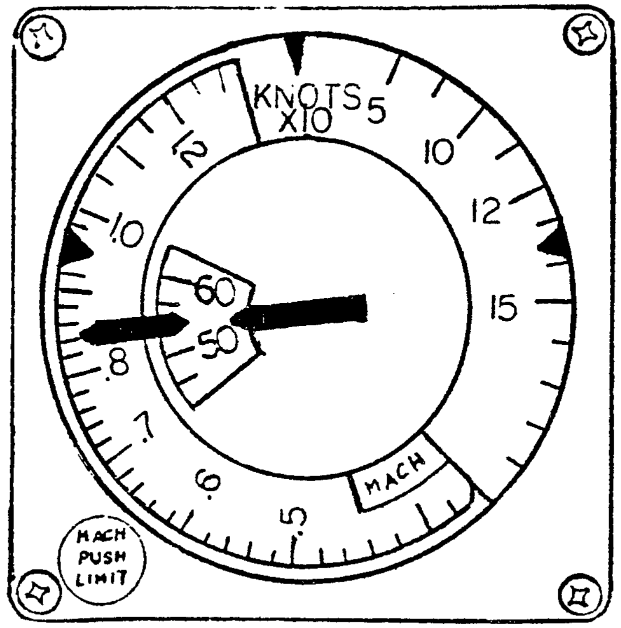
RIGHT SIDE CONSOLE

54. COMPASS CONTROL PANEL
55. CAUTION–ADVISORY INDICATOR
56. TACAN CONTROL PANEL
57. MASTER GENERATOR CONTROL PANEL
58. ARA-63 CONTROL PANEL
59. AIR CONDITIONING CONTROL PANEL
60. MASTER LIGHT CONTROL PANEL
61. EXTERNAL ENVIRONMENTAL CONTROL PANEL.
62. MASTER TEST PANEL
63. HYDRAULIC TRANSFER PUMP SWITCH
64. DEFOG CONTROL LEVER
65. WINDSHIELD DEFOG SWITCH

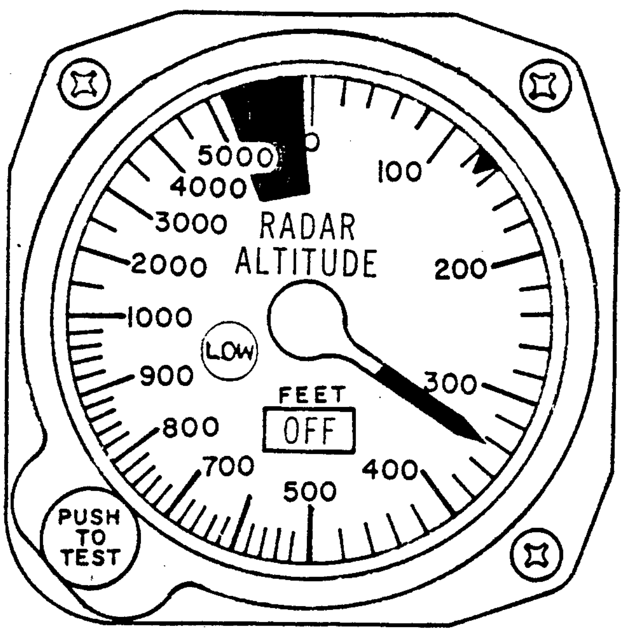
FIGURE 32. F-14 SPIN SIMULATION ACTIVE COCKPIT EQUIPMENT



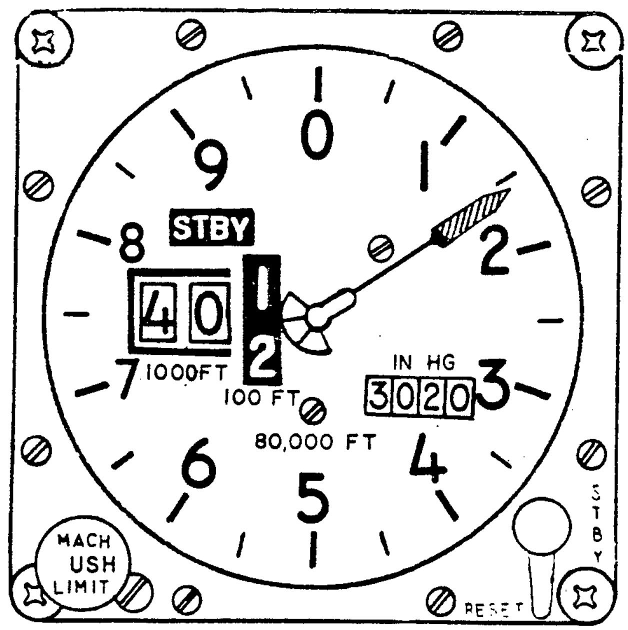
(a) RATE OF CLIMB (25)



(b) AIRSPEED (24)

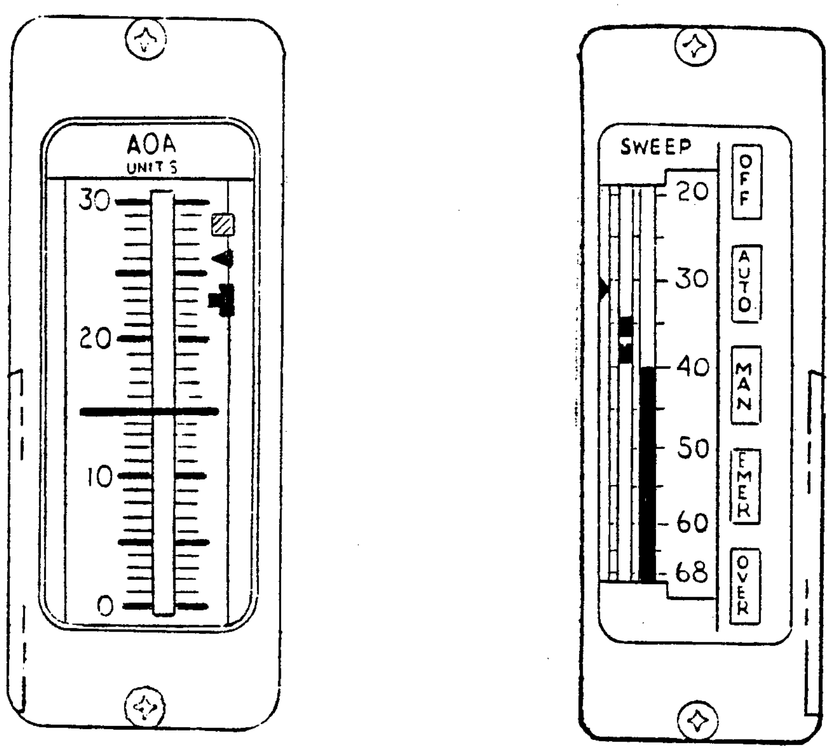


(c) RADAR ALTIMETER (22)



(d) BAROMETRIC ALTIMETER (23)

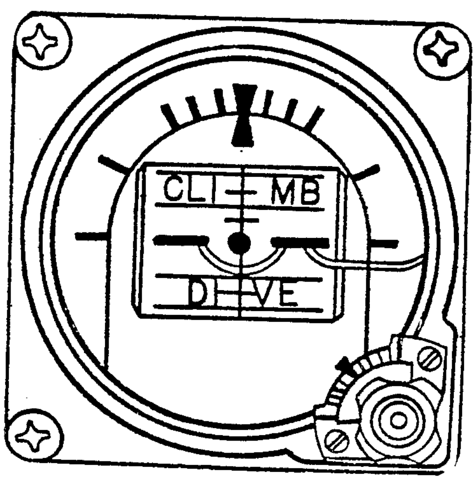
FIGURE 33.
F-14 AIRCRAFT INSTRUMENTS



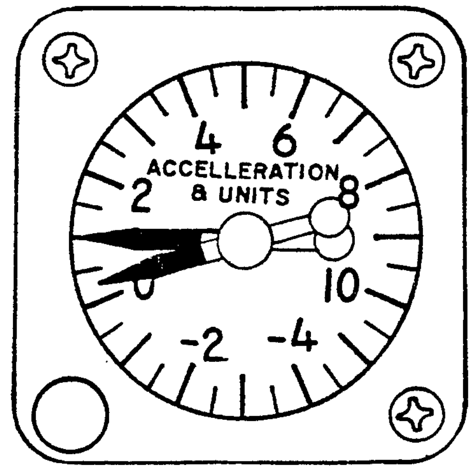
(a) ANGLE OF ATTACK (27)

(b) WING SWEEP (40)

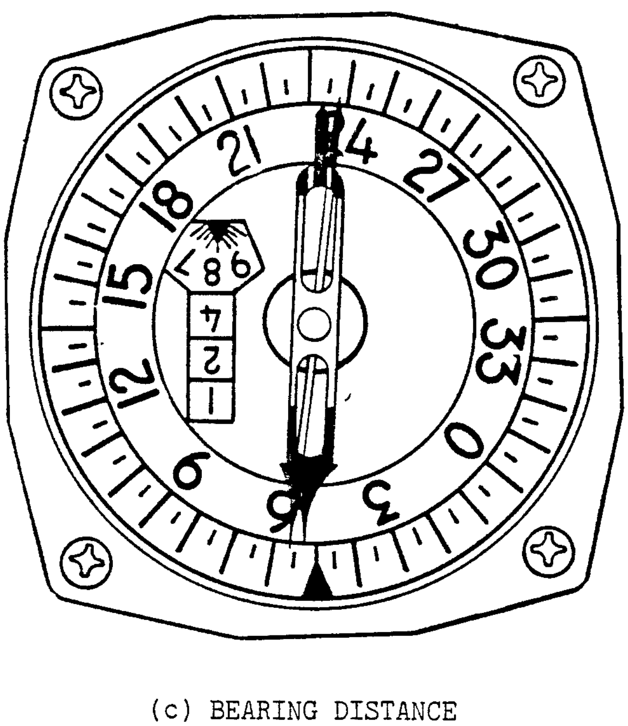
FIGURE 34.
F-14 AIRCRAFT INSTRUMENTS (Cont'd)



(a) ATTITUDE (43)

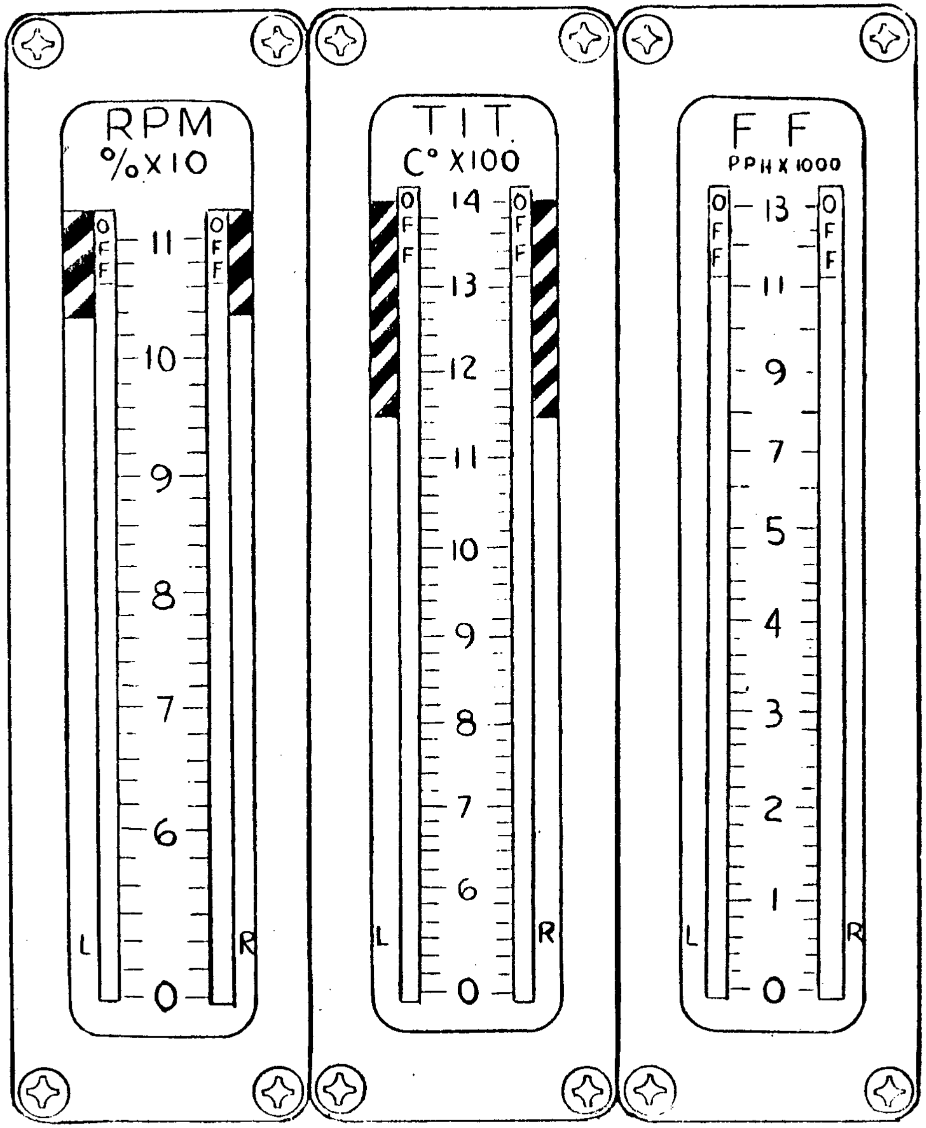


(b) ACCELEROMETER (42)



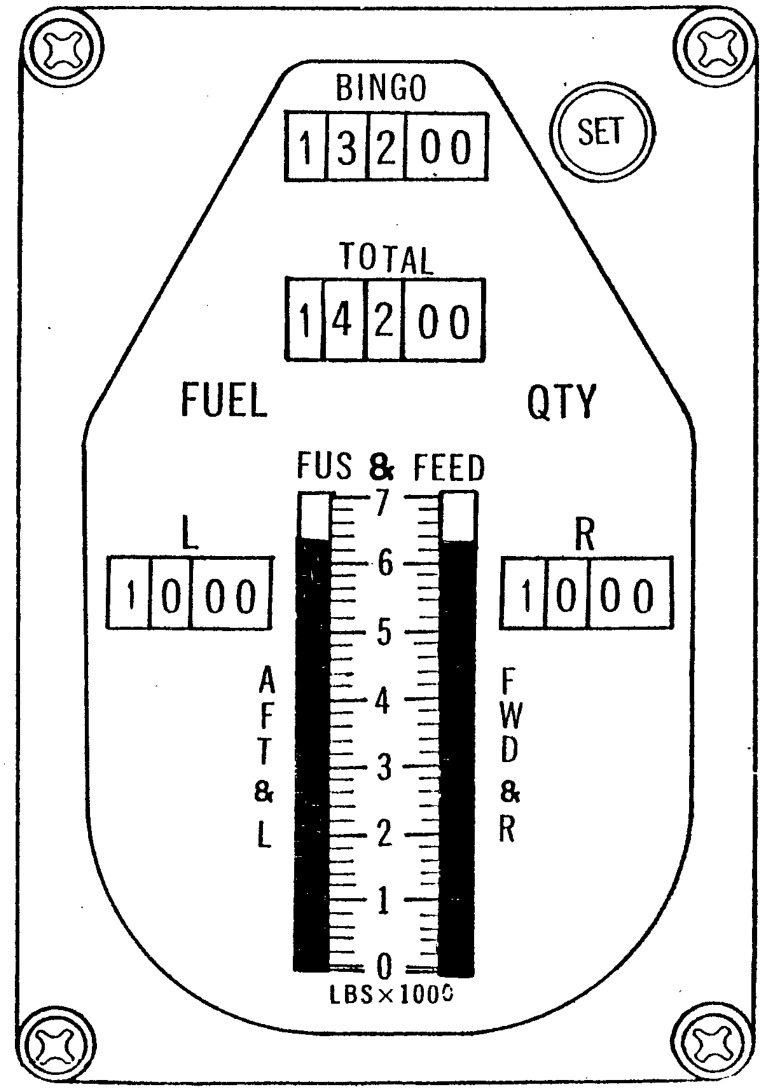
(c) BEARING DISTANCE
HEADING (46)

FIGURE 35. F-14 AIRCRAFT INSTRUMENT (Cont'd)



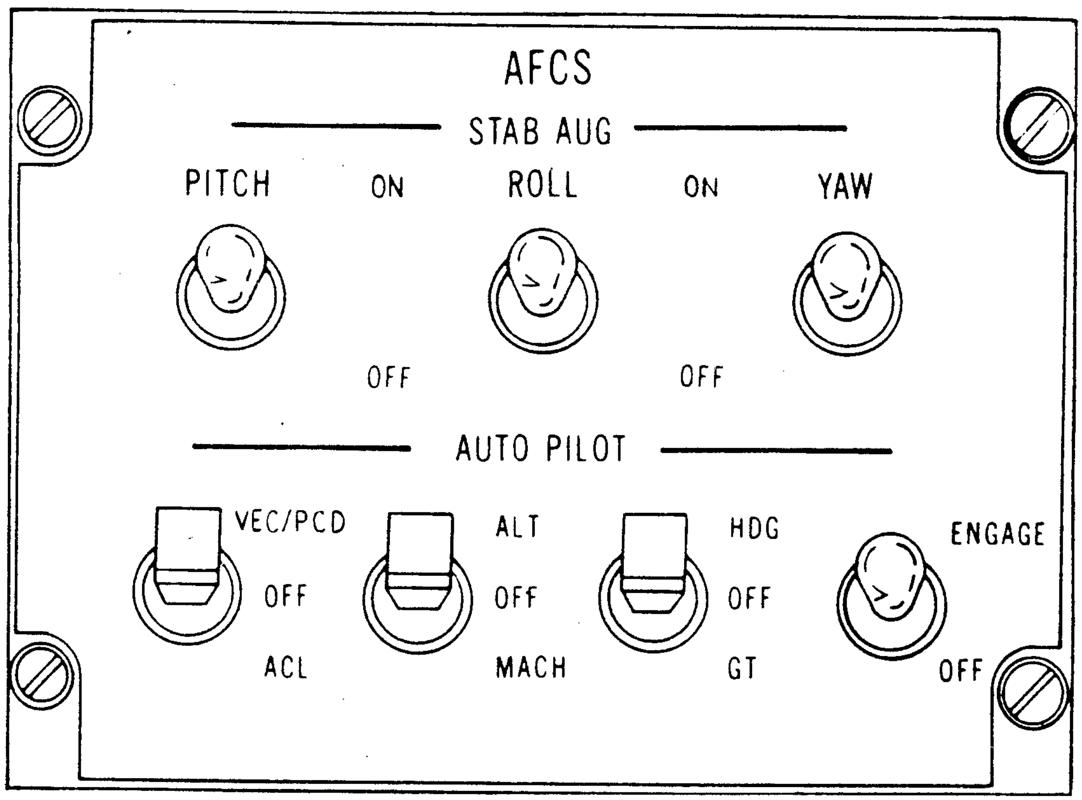
(19) (20) (21)

(a) ENGINE



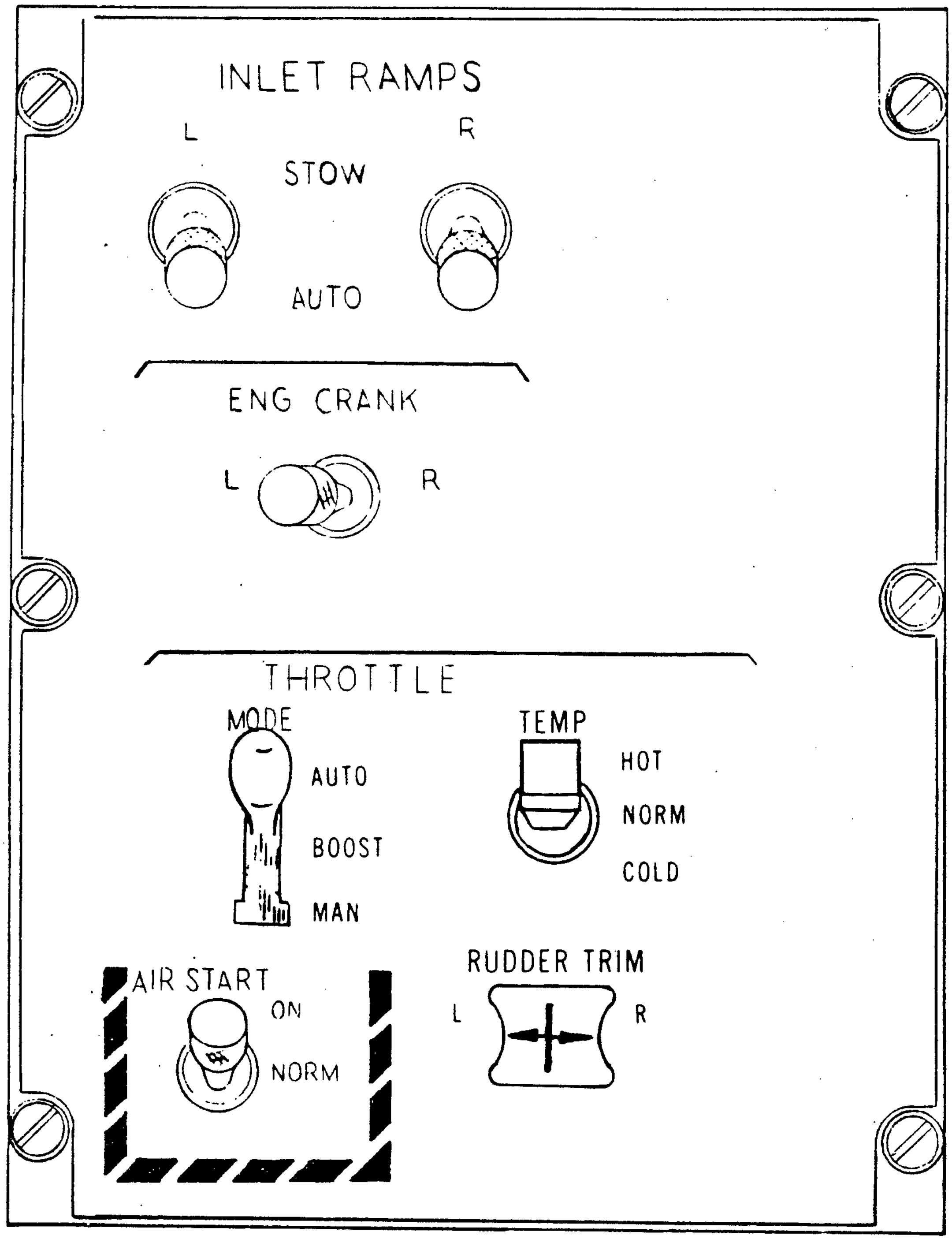
(b) QUANTITY (48)

FIGURE 36. F-14 AIRCRAFT INSTRUMENTS (Cont'd)



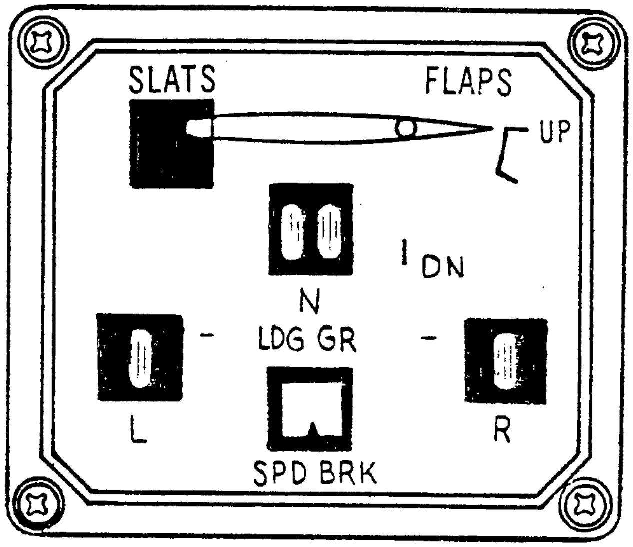
AUTO FLIGHT CONTROL (7)

FIGURE 37. F-14 AIRCRAFT PANELS

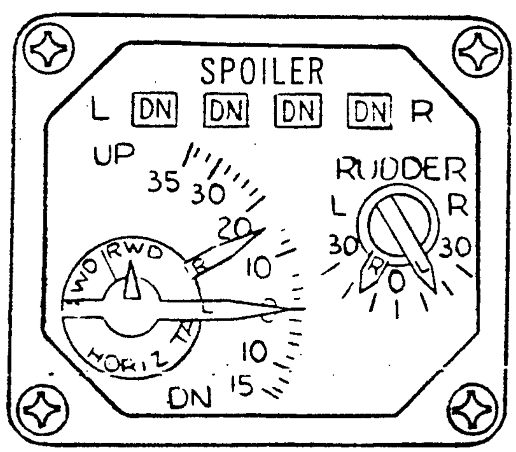


INLET RAMPS/THROTTLE (9)

FIGURE 38. F-14 AIRCRAFT PANELS (Cont'd)

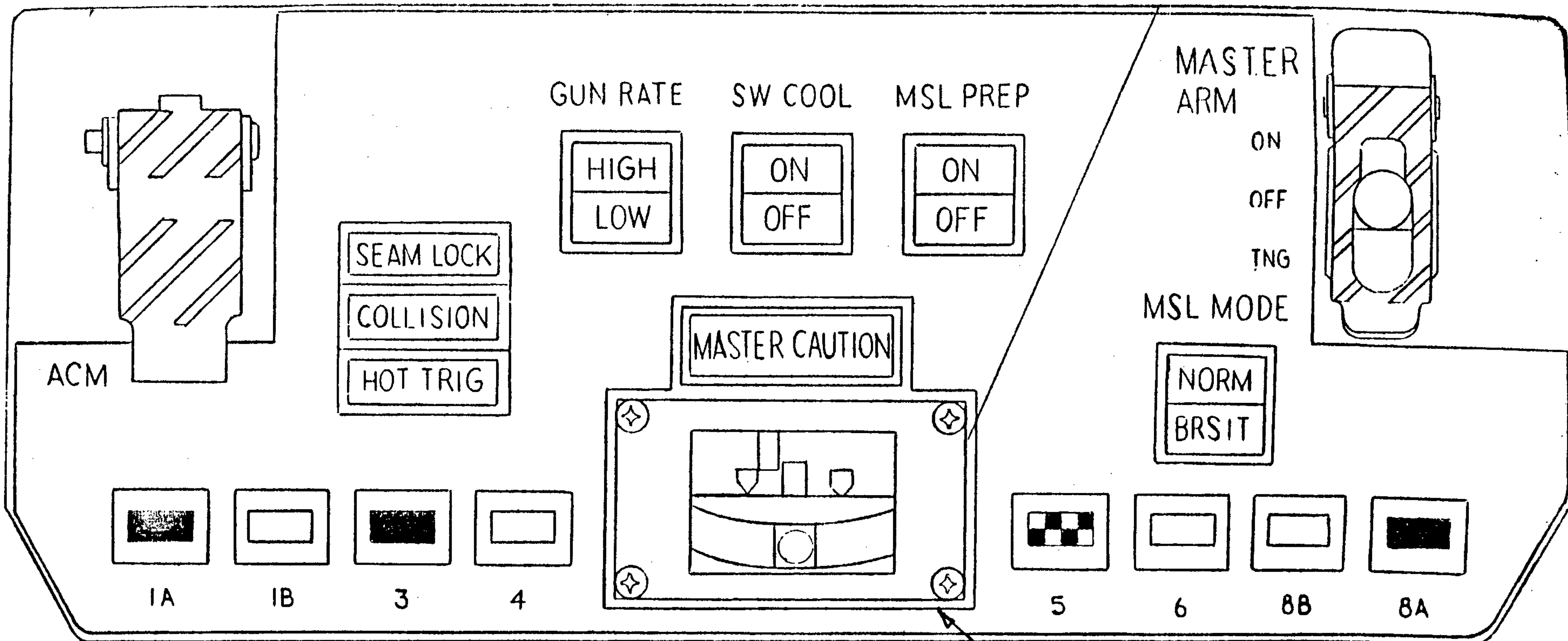


(a) FLAPS SLATS AND
SPEED BRAKE (14)



(b) SPOILERS (12)

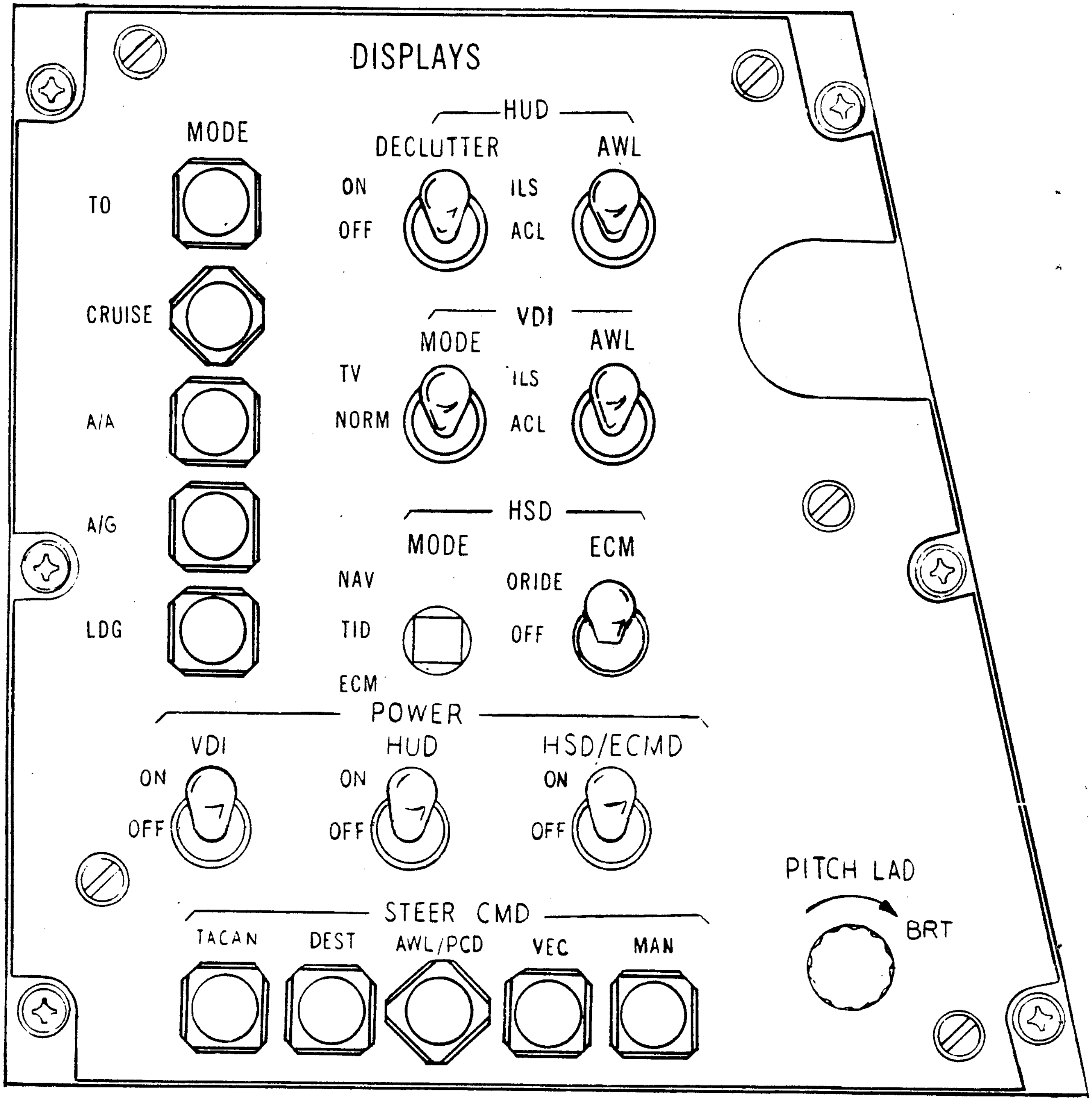
FIGURE 39. F-14 AIRCRAFT PANELS (Cont'd)



AIR COMBAT MANEUVER CONTROL (32)

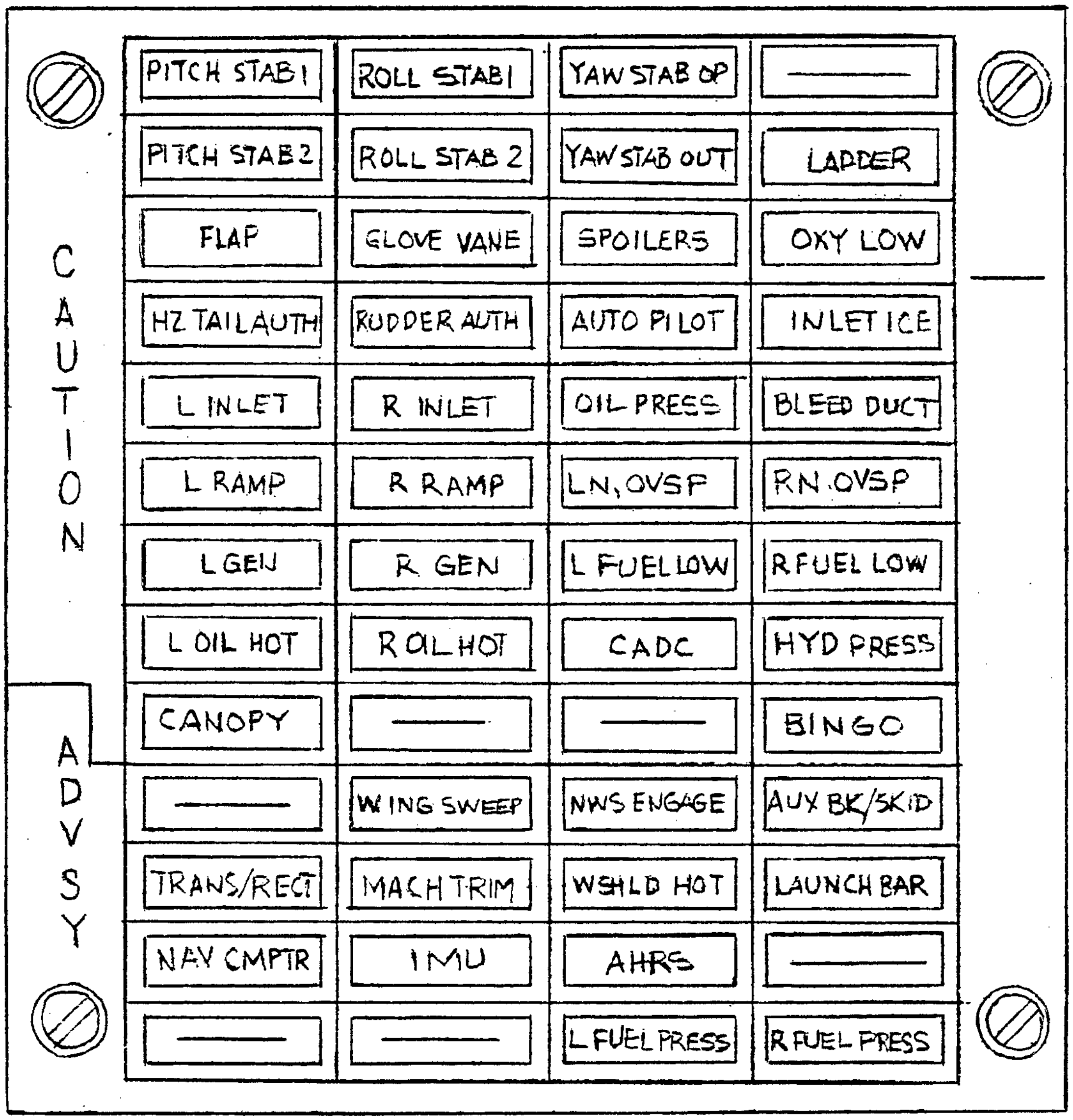
TURN AND SLIP INDICATOR (32A)

FIGURE 40. F-14 AIRCRAFT PANELS (Cont'd)



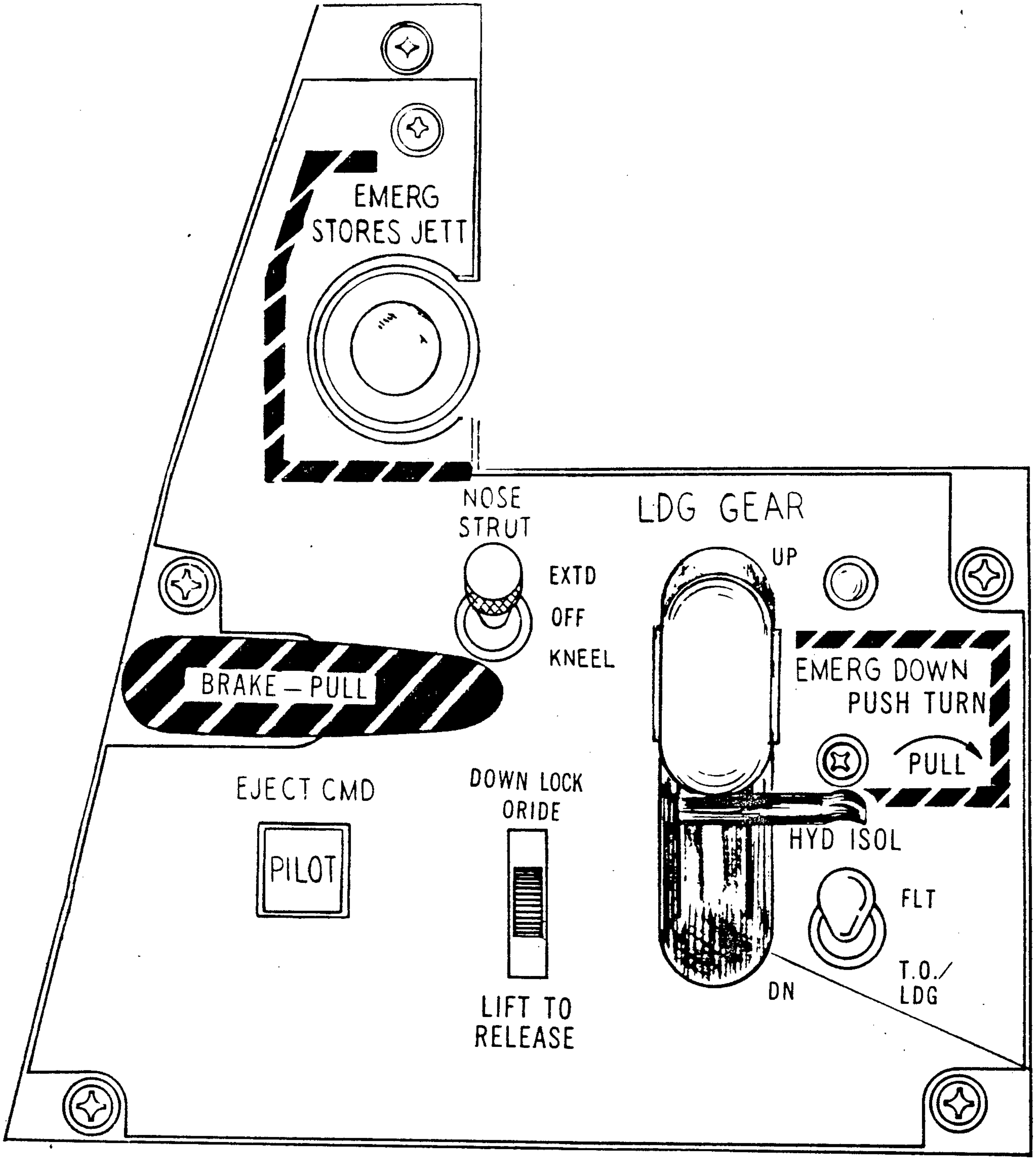
DISPLAY CONTROL (52)

FIGURE 41. F-14 AIRCRAFT PANELS (Cont'd)



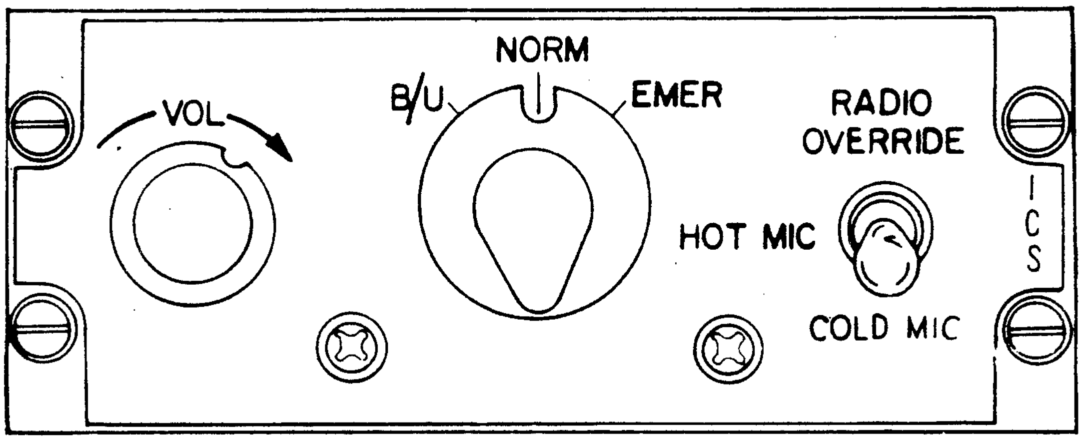
CAUTION INDICATORS (55)

FIGURE 42. F-14 AIRCRAFT PANELS (Cont'd)

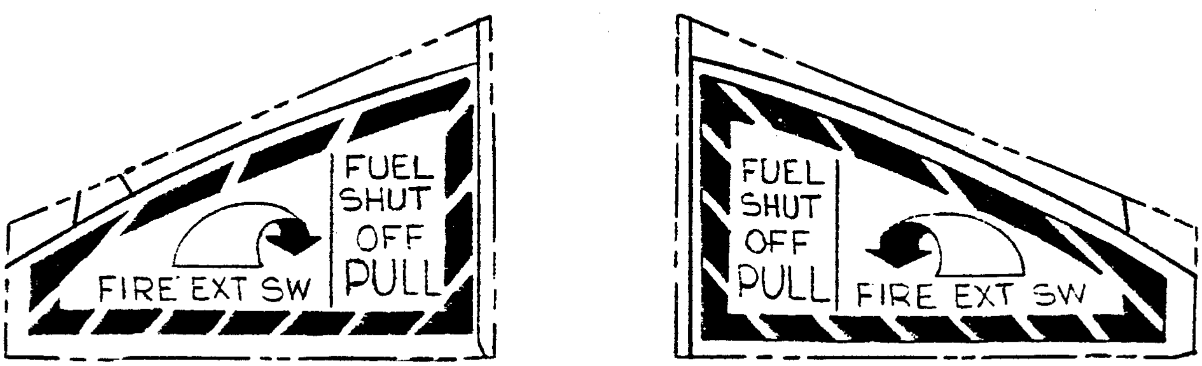


LANDING GEAR (13)

FIGURE 43. F-14 AIRCRAFT PANELS (Cont'd)



(a) COMMUNICATION (6)



(26) (41)

(b) ENGINE SHUTOFF

FIGURE 44. F-14 AIRCRAFT PANELS (Cont'd)

TABLE XXIV. AIRCRAFT COCKPIT DISPLAY DATA

DISPLAY NO.	DISPLAY	FUNCTION	PRESENTATION	VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
31	Head-Up	Tactical Info	See Figure 24	Data Req'd	1	Yes	Yes	Yes	Yes
33	Vertical Display Indicator	Attitude and Navigation	See Figure 25	Data Req'd	1	Yes	Yes	Yes	Yes
34	Horizontal Situation Display	Navigation and ECM	See Figure 26	Data Req'd	1	Yes	Yes	Yes	Yes

TABLE XXV. AIRCRAFT INSTRUMENT RANGE DATA

INST NO.	INSTRUMENT	FUNCTION	SCALE RANGE	VOLTAGE RANGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
22	RADAR ALTIMETER	ALTITUDE	0-5000 FT	±10V DC NONLINEAR Data Req'd	3D/A	Yes	No	Yes	No
23	BAROMETRIC ALTIMETER	ALTITUDE 10,000 FT COUNTER	0-100,000 FT	±10V DC	1 D/A	Yes	Yes	Yes	Yes
		1,000 FT COUNTER	0-10,000 FT	±10V DC	1 D/A	Yes	Yes	Yes	Yes
		100 FT DRUM	0-1,000 FT	±10V DC	1 D/A	Yes	Yes	Yes	Yes
		0-100 F POINTER	0-100 FT	±10V DC	1 D/A	Yes	Yes	Yes	Yes
25	RATE OF CLIMB	± FT/MIN CLIMB/ DESCENT	-6000 FPM TO +6000 FPM	±10 V DC LINEAR -10V -6000FPM -5.4V -2000FPM -4.3V -1000FPM -2.5V - 500FPM 0 0 +2.5V + 500FPM +4.3V +1000FPM +5.4V +2000FPM +10V +6000FPM	3 D/A	Yes	Yes	Yes	No

TABLE XXV. AIRCRAFT INSTRUMENT RANGE DATA

INST NO.	INSTRUMENT	FUNCTION	SCALE RANGE	VOLTAGE RANGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
24	AIRSPEED	KNOTS SPEED	0-850 KNOTS FIXED DIAL	±10V DC -10V 0 KTS -8.8V 80 KTS -7.7V 100 KTS -4.8V 150 KTS -2.3V 200 KTS -1.0V 260 KTS +1.1V 300 KTS +3.6V 400 KTS +5.5V 500 KTS +8.3V 700 KTS +10V 850 KTS	1 D/A	Yes	Yes	Yes	Yes
		MACH NO	.4-2.5 MACH NO ROTATING DIAL	±10V DC -7.5V .4 M -4.2V .6 M -1.8V .8 M 0V 1.0 M +1.5V 1.2 M +3.0V 1.6 M +5.7V 2.0 M +7.5V 2.5 M	1 D/A	Yes	Yes	Yes	Yes
27	ANGLE OF ATTACK	ANGLE OF ATTACK	0-30 UNITS REF BUGS . CLIMB 5 . CRUISE 8.5 . STALL 29	±10V DC LINEAR -10V 0 0V 15 +10V 30	1 D/A	Yes	Yes	Yes	Yes

TABLE XXV. AIRCRAFT INSTRUMENT RANGE DATA

INST NO.	INSTRUMENT	FUNCTION	SCALE RANGE	VOLTAGE RANGE		PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
40	WING SWEEP	WING SWEEP POSITION	20°-68°	±10V DC LINEAR		2 D/A	Yes	Yes	Yes	Yes
				-10V	20°					
				-7.998	25°					
				-5.984	30°					
				-3.773	35°					
		COMMAND POSITION	20°-68°	-1.982	40°	2 D/A	Yes	Yes	Yes	Yes
				- .030	45°					
				+1.861	50°					
		PROGRAM POSITION	20°-68°	+3.668	55°	2 D/A	Yes	Yes	Yes	Yes
				+5.365	60°					
				+6.624	64°					
				+7.778	68°					
				+10V	TAPE OUT OF VIEW					
		MODE FLAGS								
		OFF		OUT DISCRETE		2 O.D	Yes	Yes	Yes	Yes
		AUTO		OUT DISCRETE		2 O.D	Yes	Yes	Yes	Yes
		MAN		OUT DISCRETE		2 O.D	Yes	Yes	Yes	Yes
		EMER		OUT DISCRETE		2 O.D	Yes	Yes	Yes	Yes
		OVER		OUT DISCRETE		2 O.D	Yes	Yes	Yes	Yes

TABLE XXV. AIRCRAFT INSTRUMENT RANGE DATA

INST NO.	INSTRUMENT	FUNCTION	SCALE RANGE	VOLTAGE RANGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
43	ATTITUDE INDICATOR	PITCH	-92° to $+90^{\circ}$	±10V DC -10V -92° 0V 0° +10V $+92^{\circ}$	4 D/A	Yes	No	Yes	No
		ROLL	0° to 360°	±10V SINϕ ±10V COSϕ SEE BDHI TABLE	4 D/A 4 D/A	Yes Yes	No No	Yes Yes	No No
42	ACCELEROMETER	VERTICAL ACCELERATION	-5g to 10g	±10VDC LINEAR	1 D/A	Yes	Yes	Yes	Yes
		VERTICAL ACCELERATION (MAX) (PRE FIXED)	10g	-5g -4g -3g -2g -1g 0 DATA REQ'D +1g +2g +3g +4g +5g +6g +7g +8g +9g +10g					
		VERTICAL ACCELERATION (MIN) (PRE FIXED	-5g						

TABLE XXV. AIRCRAFT INSTRUMENT RANGE DATA

INST NO.	INSTRUMENT	FUNCTION	SCALE RANGE	VOLTAGE RANGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
46	BEARING DISTANCE HEADING INDICATOR	AIRCRAFT MAGNETIC HEADING	$0 - 360^{\circ}$	$\pm 10V\ SIN\phi$	3 D/A	Yes	Yes	Yes	No
				$\pm 10V\ COS\phi$	3 D/A	Yes	Yes	Yes	No
		BEARING TO UHF/ADF STATION (NO 1 POINTER)	$0 - 360^{\circ}$	$\pm 10V\ SIN\phi_2$	3 D/A	Yes	No	No	No
				$\pm 10V\ COS\phi_2$	3 D/A	Yes	No	No	No
		MAGNETIC COURSE TO TACAN STATION	$0 - 360^{\circ}$	$\pm 10V\ SIN\phi_3$	3 D/A	Yes	No	No	No
				$\pm 10V\ COS\phi_3$	3 D/A	Yes	No	No	No
				0 / SIN VOLTS / COS VOLTS					
				0 / 0 / +10.0					
				45 / +7.07 / +7.07					
				90 / +10.0 / 0					
				135 / +7.07 / -7.07					
				180 / 0 / -10.0					
				225 / -7.07 / -7.07					
				270 / -10.0 / 0					
				315 / -7.07 / +7.07					
				0 / 0 / +10.0	3 D/A	Yes	No	No	No
		SLANT RANGE (NAU MILES) TO TACAN STATION	HUNDREDS	$\pm 10V\ SIN\phi_4$	3 D/A	Yes	No	No	No
			TENS	$\pm 10V\ COS\phi_4$	3 D/A	Yes	No	No	No
			UNITS	$1\ UNIT = 36^{\circ}$	3 D/A	Yes	No	No	No
					3 D/A	Yes	No	No	No
					3 D/A	yes	No	No	No

TABLE XXV. AIRCRAFT INSTRUMENT RANGE DATA

INST NO.	INSTRUMENT	FUNCTION	SCALE RANGE	VOLTAGE RANGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
45	CLOCK		0-12 HRS	HAND WOUND	4	-	-	-	-
19	ENGINE	ENGINE % RPM RIGHT & LEFT (2 TAPES)	0 TO 110%	±10V DC	1 D/A	Yes	Yes	Yes	Yes
				-10V RED "OFF" FLAG; -7.792 0; +10V 110	1 D/A	Yes	Yes	Yes	Yes
		TURBINE INLET TEMP RIGHT & LEFT (2 TAPES)	0 TO 1400°C	±10V DC	1 D/A	Yes	Yes	Yes	Yes
				-10V RED "OFF" FLAG; -7.792 0; +10V 1400°C	1 D/A	Yes	Yes	Yes	Yes
21		FUEL FLOW RIGHT & LEFT (2 TAPES)	0 TO 13000 PPH	±10V DC	1 D/A	Yes	Yes	Yes	Yes
				-10V RED "OFF" FLAG; -7.792 0; +10V 13000 PPH	1 D/A	Yes	Yes	Yes	Yes

TABLE XXV. AIRCRAFT INSTRUMENT RANGE DATA

INST NO.	INSTRUMENT	FUNCTION	SCALE RANGE	VOLTAGE RANGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
48	FUEL QUANTITY	DISPLAY FUEL AVAILABLE IN AFT FUSELAGE & LEFT FEED TANK	0 LBS TO 7305 LBS	±10V DC -9.2V 0 LBS +9.2V 7000 LBS +10V 7305 LBS	4 D/A	No	No	No	No
		DISPLAY FUEL AVAILAVLE IN FWD FUSELAGE & RIGHT FEED TANK	0 LBS TO 7305 LBS	SAME AS ABOVE	4 D/A	No	No	No	No
		COUNTER FUEL AVAILAVLE IN LEFT WING TANK	DRUM 1 0 TO 9 DRUM 2 1 TO 9 WITH BLANK FOR ZERO	±10V DC -9.2V 0 LBS +9.2V 2300 LBS +10V 2400 LBS	4 D/A 4 D/A	No No	No No	No No	No No
		COUNTER FUEL AVAILABLE IN RIGHT WING TANK	DRUM 1 0 TO 9 DRUM 2 1 TO 9 WITH BLANK FOR ZERO	SAME AS ABOVE	4 D/A 4 D/A	No No	No No	No No	No No

TABLE XXV. AIRCRAFT INSTRUMENT RANGE DATA

INST NO.	INSTRUMENT	FUNCTION	SCALE RANGE	VOLTAGE RANGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
(CONT) 48	FUEL QUANTITY	COUNTER TOTAL FUEL	DRUMS 1 & 2 0 TO 9 DRUM 3 1 TO 9 WITH BLANK FOR ZERO	±10V DC	4 D/A	No	No	No	No
				-9.2V 0 LBS +9.2V 2300 LBS +10V 2400 LBS	4 D/A	No	No	No	No
		COUNTER BINGO	-600 LBS TO 22,500 LBS	MANUAL INPUT	4 D/A	No	No	No	No
32A	TURN AND SLIP	VEL VECTOR		METER MOVEMENT	1 D/A	Yes	Yes	Yes	Yes
		RATE OF TURN		DATA REQ'D	1 D/A	Yes	Yes	Yes	Yes

TABLE XXVI. AIRCRAFT FLIGHT CONTROL RANGE DATA

FLIGHT CONTROL NO.	FLIGHT CONTROL	SWITCH FUNCTION	POT. SIGNAL FUNCTION/ RANGE	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
37	CONTROL STICK & RUDDERS		PITCH +5 IN TO -7 IN	A/D SIGNAL ±10V DC +5 IN 5V +4 IN 4V +3 IN 3V +2 IN 2V +1 IN 1V 0 0V -1 IN -1V -2 IN -2V -3 IN -3V -4 IN -4V -5 IN -5V -6 IN -6V -7 IN -7V	1 A/D	Yes	Yes	Yes	Yes
			ROLL +7 IN TO -7 IN	A/D SIGNAL ±10V DC +7 IN 7V +6 IN 6V +5 IN 5V +4 IN 4V +3 IN 3V +2 IN 2V +1 IN 1V 0 0 -1 IN -1V -2 IN -2V	1 D/A	Yes	Yes	Yes	Yes

TABLE XXVI. AIRCRAFT FLIGHT CONTROL RANGE DATA

FLIGHT CONTROL NO.	FLIGHT CONTROL	SWITCH FUNCTION	POT. SIGNAL FUNCTION/ RANGE	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
(CONT) 37	CONTROL STICK & RUDDERS		ROLL +7 IN TO -7 IN	-3 IN -3V -4 IN -4V -5 IN -5V -6 IN -6V -7 IN -7V					
			YAW +3.25 IN TO -3.25 IN	A/D SIGNAL +10V DC	1 A/D	Yes	Yes	Yes	Yes
				+3.25 IN 3.25V +3 IN 3V +2 IN 2V +1 IN 1V 0 0 -1 IN -1V -2 IN -2V -3 IN -3V -3.25 IN -3.25V					
		1 BOMB RELEASE BUTTON	-	INDISCRETE	4 ID	No	No	No	No
		2. PITCH & ROLL TRIM							
		PITCH UP	-	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		PITCH DOWN	-	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		ROLL UP	-	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		ROLL DOWN	-	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		NEUTRAL	-	OPEN					

TABLE XXVI. AIRCRAFT FLIGHT CONTROL RANGE DATA

FLIGHT CONTROL NO.	FLIGHT CONTROL	SWITCH FUNCTION	POT. SIGNAL FUNCTION/ RANGE	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
(CONT) 37	CONTROL STICK & RUDDERS	3. WEAPON SELECT							
		SPARROW OR PHOENIX	-	INDISCRETE	4 ID	No	No	No	No
		SIDEWINDER	-	INDISCRETE	4 ID	No	No	No	No
		GUN	-	INDISCRETE	4 ID	No	No	No	No
		OFF	-	OPEN					
		4. MANRUVER FLAP/SLAT THUMBWHEEL							
		NEUTRAL	-	OPEN					
		FWR RETRACTS FLAPS/SLATS	-	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		AFT EXTENDS FLAPS/SLATS	-	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		5. DLC ENGAGE	-	INDISCRETE	4 ID	No	No	No	No
		6. AUTO PILOT REF	-	INDISCRETE	4 ID	No	No	No	No
		7. AUTO PILOT EMER DISENGAGE	-	INDISCRETE	1 ID	Yes	Yes	Yes	Yes

TABLE XXVI. AIRCRAFT FLIGHT CONTROL RANGE DATA

FLIGHT CONTROL NO.	FLIGHT CONTROL	SWITCH FUNCTION	POT. SIGNAL FUNCTION/ RANGE	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
(CONT) 37	CONTROL STICK & RUDDERS	8. CAMERA & FWD WEAPON FIRING							
		NEUTRAL	-	OPEN					
		CAMERA	-	--					
		WEAPON FIRING	-	INDISCRETE	4 ID	No	No	No	No
8	THROTTLE		THROTTLE CONTROL	$\pm$10V DC					
			RIGHT	OFF IDLE MIL MAX	1 A/D	Yes	Yes	Yes	Yes
			LEFT		1 A/D	Yes	Yes	Yes	Yes
		1. THROTTLE CONTROL							
		RIGHT							
		OFF		OPEN					
		IDLE		INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		MILL		INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		LEFT							
		OFF		OPEN					
		IDLE		INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		MIL		INDISCRETE	1 ID	Yes	Yes	Yes	Yes

TABLE XXVI. AIRCRAFT FLIGHT CONTROL RANGE DATA

FLIGHT CONTROL NO.	FLIGHT CONTROL	SWITCH FUNCTION	POT. SIGNAL FUNCTION/ RANGE	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
(CONT) 8	THROTTLE	2. SPEED BRAKE							
		EXT		INDISCRETE	2 ID	Yes	Yes	Yes	Yes
		RET		INDISCRETE	2 ID	Yes	Yes	Yes	Yes
		CENTER		OPEN					
		3. WING SWEEP MODE							
		AUTO	-	INDISCRETE	2 ID	Yes	Yes	Yes	Yes
		BOMB	-	INDISCRETE	2 ID	Yes	Yes	Yes	Yes
		AFT	-	INDISCRETE	2 ID	Yes	Yes	Yes	Yes
		FWD	-	INDISCRETE	2 ID	Yes	Yes	Yes	Yes
		NEUTRAL	-	OPEN					
			EMER WING SWEEP	$\pm$10V DC					
			68° TO 20°	20°	2 A/D	Yes	Yes	Yes	Yes
			OVERSWEEP	30°					
			68° TO 75°	40°					
				50°					
				60°					
				68°					
				70°					
				75°					

TABLE XXVI. AIRCRAFT FLIGHT CONTROL RANGE DATA

FLIGHT CONTROL NO.	FLIGHT CONTROL	SWITCH FUNCTION	POT. SIGNAL FUNCTION/ RANGE	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
(CONT) 8	THROTTLE		FLAP HANDLE EMER DN DOWN UP EMER UP	±10V DC EMER DN DOWN UP EMER UP	2 A/D	Yes	Yes	Yes	Yes

TABLE XXVII. AIRCRAFT PANELS SWITCH AND INDICATOR DATA

PANEL NO.	PANEL	SWITCH FUNCTION	INDICATOR FUNCTION	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
7	AUTO FLIGHT CONTROL	1. PITCH STAB AUG	UNIT 31	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		2. ROLL STAB AUG	UNIT 31	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		3. YAW STAB AUG	UNIT 31	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		4. AUTO PILOT ENGAGE - OFF	UNIT 31	INDISCRETE	4 ID	No	No	No	No
		5. AUTO PILOT							
		HDG		INDISCRETE	4 ID	No	No	No	No
		OFF		OPEN					
		GT		INDISCRETE	4 ID	No	No	No	No
		6. AUTO PILOT							
		ALT		INDISCRETE	4 ID	No	No	No	No
		OFF		OPEN					
		MACH		INDISCRETE	4 ID	No	No	No	No
		7. VEC/PCD							
		OFF		OPEN					
		ACL		INDISCRETE	4 ID	No	No	No	No

TABLE XXVII. AIRCRAFT PANELS SWITCH AND INDICATOR DATA

PANEL NO.	PANEL	SWITCH FUNCTION	INDICATOR FUNCTION	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
9	AUTO THROTTLE CONTROL	1. THROTTLE MODE							
		AUTO	UNITS	INDISCRETE	4 ID	No	No	No	No
		BOOST	---	INDISCRETE	4 ID	No	No	No	No
		MAN	---	INDISCRETE	4 ID	No	No	No	No
		2. THROTTLE TEMP							
		HOT	---	INDISCRETE	4 ID	No	No	No	No
		NORM	---	OPEN					
		COLD	---	INDISCRETE	4 ID	No	No	No	No
		3. RUDDER TRIM							
		LEFT	---	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		RIGHT	---	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		4. AIR START							
		ON	---	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
		NORM	---	INDISCRETE	1 ID	Yes	Yes	Yes	Yes
9	INLET RAMPS	INLET RAMPS							
		LEFT							
		STOW		INDISCRETE	4 ID	No	No	No	No
		AUTO		OPEN					
		RIGHT							
		STOW		INDISCRETE	4 ID	No	No	No	No
		AUTO		OPEN					

TABLE XXVII. AIRCRAFT PANELS SWITCH AND INDICATOR DATA

PANEL No.	PANEL	SWITCH FUNCTION	INDICATOR FUNCTION	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
14	FLAPS SLATS & SPEED BRAKE INDICATOR		1. FLAPS						
		UNIT 21	Flaps Up	OPEN					
		UNIT 21	Flaps Down 10^{o}	OUTDISCRETE	1 OD	Yes	Yes	Yes	Yes
		UNIT 21	Flaps Down 35^{o}	OUTDISCRETE	1 ID	Yes	Yes	Yes	Yes
	INDICATOR		2. SLATS						
		UNIT 20	Power Off	OPEN					
		UNIT 20	Slats Ext 17^{o}	OUTDISCRETE	1 OD	Yes	Yes	Yes	Yes
		UNIT 20	Slats Ret 0^{o}	OUTDISCRETE	1 OD	Yes	Yes	Yes	Yes
			3. SPEED BRAKES						
		UNIT 21	Partial Ext.	OUTDISCRETE	2 OD	Yes	Yes	Yes	Yes
		UNIT 21	Full Ext 60^{o}	OUTDISCRETE	2 OD	Yes	Yes	Yes	Yes
		UNIT 21	Full Ret	OUTDISCRETE	2 OD	Yes	Yes	Yes	Yes
		UNIT 21	Power Off	OPEN					

TABLE XXVII. AIRCRAFT PANELS SWITCH AND INDICATOR DATA Page 4 of 8

PANEL NO.	PANEL	SWITCH FUNCTION	INDICATOR FUNCTION	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
(CONT) 14	FLAPS SLATS SPEED BRAKES	UNIT 33	Gear DN	OUTDISCRETE	4 OD	No	No	No	No
			LEFT OFF	OPEN					
			Gear Up	OUTDISCRETE	4 OD	No	No	No	No
			Gear Dn	OUTDISCRETE	4 OD	No	No	No	No
			RIGHT OFF	OPEN					
			Gear Up	OUTDISCRETE	4 OD	No	No	No	No
12	SPOILER		1. SPOILER LEFT						
			OUT	2 INDICATOR PAIRS	3 OD	Yes	Yes	Yes	No
			INBOARD		3 OD	Yes	Yes	Yes	No
			FIGHT						
			IN		3 OD	Yes	Yes	Yes	No
			OUTBOARD		3 OD	Yes	Yes	Yes	No
			DN Down	OUTDISCRETE	3 OD	Yes	Yes	Yes	No
			 Ext 70°	OUTDISCRETE	3 OD	Yes	Yes	Yes	No
			 Dropped 4½°	OUTDISCRETE	3 OD	Yes	Yes	Yes	NO

TABLE XXVII. AIRCRAFT PANELS SWITCH AND INDICATOR DATA

PANEL NO.	PANEL	SWITCH FUNCTION	INDICATOR FUNCTION	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
12	SPOILER		2. RUDDER POSITION	±10V DC LINEAR					
		UNIT 20	. RIGHT 0-30	A/D SIGNAL	3 D/A	Yes	No	Yes	No
		UNIT 20	. LEFT 0-30	A/D SIGNAL	3 D/A	Yes	No	Yes	No
			3. HORIZ TAIL POSITION	±10V DC					
			. RIGHT WING -15° TO 35°	A/D SIGNAL	3 D/A	Yes	No	Yes	No
			. LEFT WING -15° TO 35°	A/D SIGNAL	3 D/A	Yes	No	Yes	No
32	AIR COMBAT MANEUVER CONTROL	1. ACM JETT (PUSH BUT)		INDISCRETE	4 ID	No	No	No	No
		2. MASTER CAUTION		OUTDISCRETE	1 OD	Yes	Yes	Yes	Yes

TABLE XXVII. AIRCRAFT PANELS SWITCH AND INDICATOR DATA

PANEL NO.	PANEL	SWITCH FUNCTION	INDICATOR FUNCTION	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
52	DISPLAY CONTROL	MODE							
		1. TAKE OFF	UNITS 1 & 3	INDISCRETE	4 ID	No	No	No	No
		2. CRUSE	UNITS 1 & 3	INDISCRETE	4 ID	No	No	No	No
		3. A/A	UNITS 1 & 3	INDISCRETE	4 ID	No	No	No	No
		4. A/G	UNITS 1 & 3	INDISCRETE	4 ID	No	No	No	No
		5. LDG	UNITS 1 & 3	INDISCRETE	4 ID	No	No	No	No
		STEER COMMAND							
		6. TACAN	UNIT 2	INDISCRETE	4 ID	No	No	No	No
		7. DEST.	UNIT 2	INDISCRETE	4 ID	No	No	No	No
		8. AWL/PCD	UNIT 2	INDISCRETE	4 ID	No	No	No	No
		9. VEC D/L DEV	UNIT 2	INDISCRETE	4 ID	No	No	No	No
		10. MANUAL COURSE & HEADING	UNIT 2	INDISCRETE	4 ID	No	No	No	No
		POWER							
		11. VDI	UNIT 1	115V AC - 400 HZ	4 Power	Yes	-	-	-
		12. HUD	UNIT 3		4 Power	Yes	-	-	-
		13. HSD	UNIT 2	115V AC - 400 HZ	4 Power	Yes	-	-	-
		DISPLAY MODES							
		14. DECLUTTER ON OFF	UNIT 3 UNIT 3	INDISCRETE OPEN	2 ID	Yes	Yes	Yes	Yes
		15. VDI TV NORM	UNIT 1 UNIT 1	INDISCRETE OPEN	4 ID	No	No	No	No

TABLE XXVII. AIRCRAFT PANELS SWITCH AND INDICATOR DATA

PANEL NO.	PANEL	SWITCH FUNCTION	INDICATOR FUNCTION	SIGNAL/ VOLTAGE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
(CONT) 52	DISPLAY CONTROL	16. HSD							
		NAV	UNIT 2	OPEN					
		TID	UNIT 2	INDISCRETE	4 ID	No	No	No	No
		ECM	-	-					
		17. PITCH LAD BRT			1 Power	Yes	-	-	-
55	CAUTION	UNIT 25	PITCH STAB 1	OUTDISCRETE	2 OD	Yes	Yes	Yes	Yes
		UNIT 25	PITCH STAB 2	OUTDISCRETE	2 OD	Yes	Yes	Yes	Yes
		UNIT 25	ROLL STAB 1	OUTDISCRETE	2 OD	Yes	Yes	Yes	Yes
		UNIT 25	ROLL STAB 2	OUTDISCRETE	2 OD	Yes	Yes	Yes	Yes
		UNIT 25	YAW STAB OP	OUTDISCRETE	2 OD	Yes	Yes	Yes	Yes
		UNIT 25	YAW STAB OUT	OUTDISCRETE	2 OD	Yes	Yes	Yes	Yes
			L FUEL PRESS	OUTDISCRETE	2 OD	Yes	Yes	Yes	Yes
			R FUEL PRESS	OUTDISCRETE	2 OD	Yes	Yes	Yes	Yes
14A	EMER JETTISON	EMER STORES JETTISON		INDISCRETE	4 ID	No	No	No	No
13	LANDING GEAR	1. LANDING GEAR HANDLE NORMAL							
		UP		INDISCRETE	2 ID	Yes	No	No	No
		DOWN		INDISCRETE	2 ID	Yes	No	No	No
		EMER DOWN		INDISCRETE	2 ID	Yes	No	No	No

TABLE XXVII. AIRCRAFT PANELS SWITCH AND INDICATOR DATA

PANEL No	PANEL	SWITCH FUNCTION	INDICATOR FUNCTION	SIGNAL/ VOLGATE	PRIORITY 1 MUST 2 TEST PLAN 3 FUTURE 4 NO	J-BOX	MICRO PROCESSOR	MODEL	SOFTWARE
41	ENGINE SHUTOFF	ENGINE SHUTOFF RIGHT		INDISCRETE	4 ID	No	No	No	No
26		LEFT		INDISCRETE	4 ID	No	No	No	No
6	COMMUNICATION				4	No	No	No	No

2.3.4 Data Processing/Crewstation Drive Interface System

The Data Processing/Crewstation Drive Interface System (AREA 2) highlighted in Figure 45, consists of the CDC 6600 Digital Computer/Simulation Control Computer Fiber Optic Data Link, 25 coax lines connecting the SCD Hybrid Analog Computer with the ACSTD Analog Computer, 54 twisted pair connecting the SCD Hybrid Analog Computer with the Dynamic Flight Simulator Signal Distribution System, and 8 twisted pair/double shielded lines connecting the ACSTD IDI Display Computer with the Signal Distribution System.

2.3.4.1 Fiber Optic Data Link

2.3.4.1.1 Background

The Fiber Optic Data Link System allows the flow of digital data between the CDC 6600 Central Computer System, located in Building 1, and the Univac V77-600 Minicomputer (SCC), located in the Centrifuge Area, Building 70. (Refer to Figure 46). The CDC 6600 requires high speed transfer of data between the two computers thereby necessitating the selection of bit slice microprocessor technology.

The data is sent over the Fiber Optic Link in a full duplex, bi-phase format at a 5 MHz rate. Data is transferred in blocks consisting of 256 16-bit data words. The data is buffered by a 256 by 16-bit word FIFO memory buffer. The first 192 words are by-passed until the last 64 words are filled in order to cut down on the initial propagation delay of the FIFO. As the data is sent from the FIFO buffer to the computer I/O of the Fiber Optic Serial Encoder, it is also loaded into a recirculating buffer which consists of a second 256 by 16-bit FIFO memory buffer. This buffer is utilized if retransmission of the data is required due to an error in the original data transmission.

The FIFO data that is being sent over the Fiber Optic Link is also loaded into an 8x01 cyclic redundancy check generator in order that a remainder check word may be sent along with the data so that the validity of the data block can be checked. The time required for transmission of the data block is 2.1 milliseconds.

In order to supplement the data link, analog lines were also installed to provide a means of sending data between the ACSTD analog computer and the SCD analog computer.

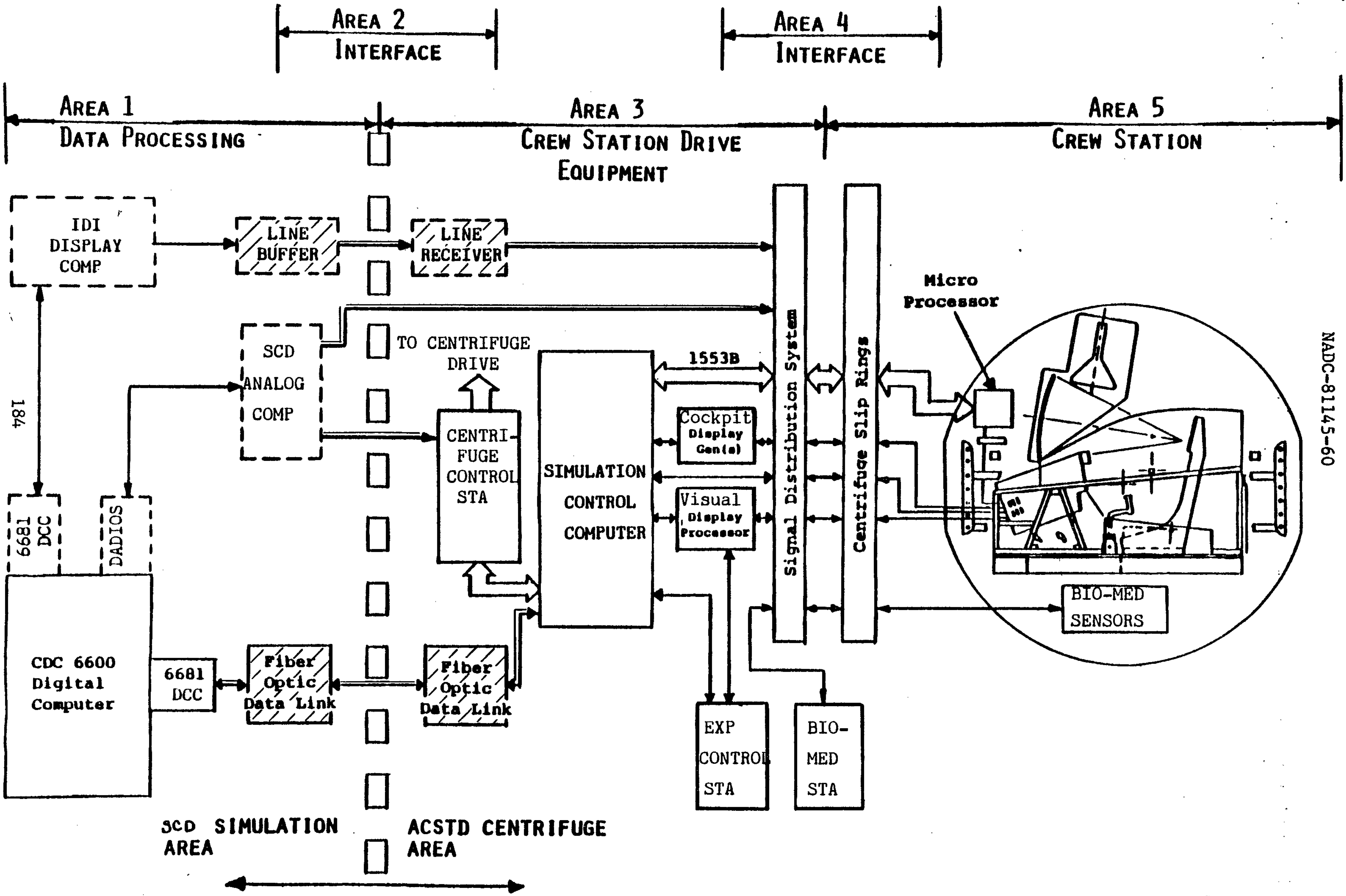


FIGURE 45. DFS DATA PROCESSING/CREWSTATION DRIVE INTERFACE EQUIPMENT (AREA 2)

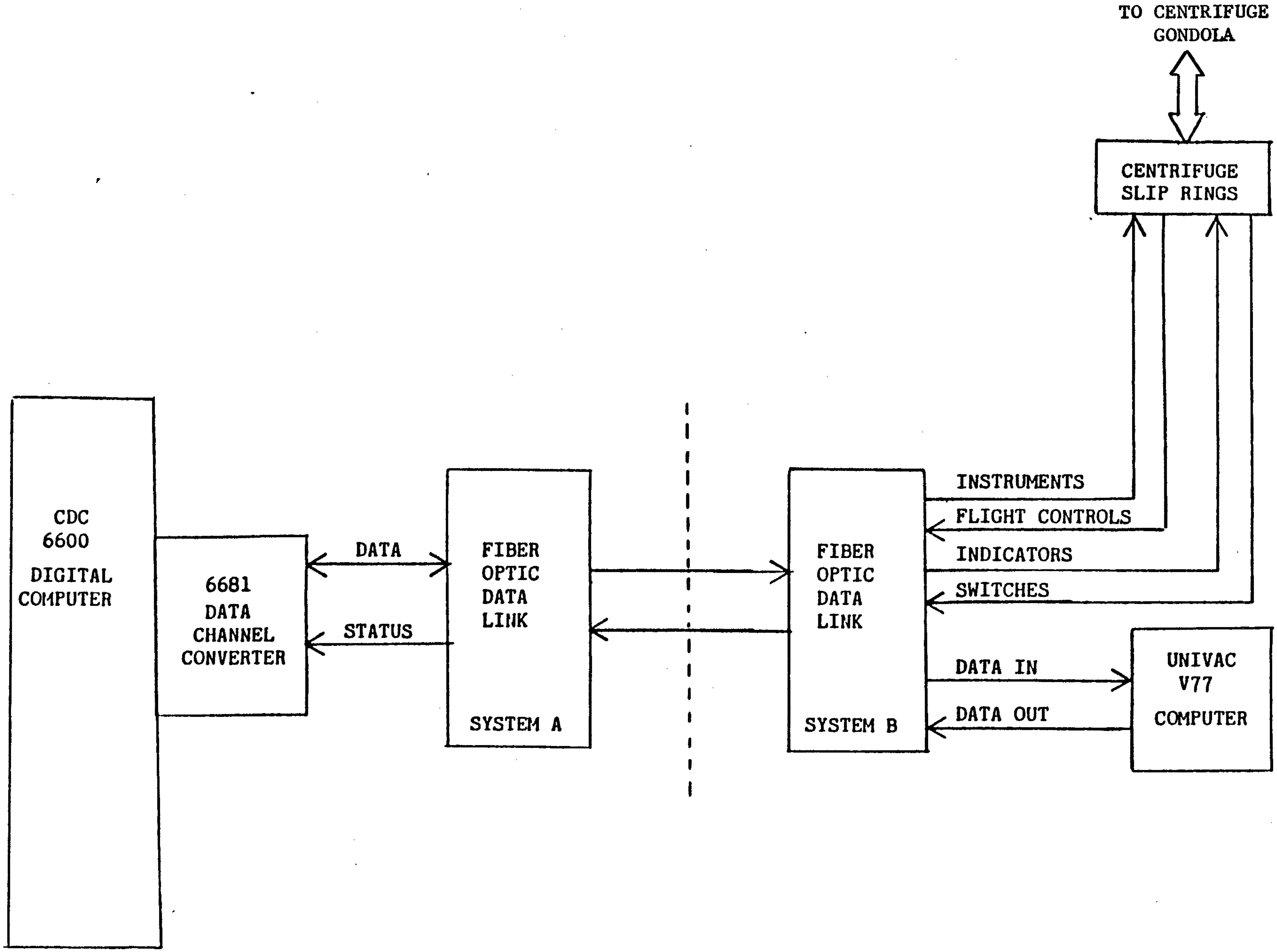


FIGURE 46. **OVERALL BLOCK DIAGRAM OF FIBER OPTIC DATA LINK SYSTEM**

2.3.4.1.2 Hardware

The Fiber Optic Link utilizes three Texas Instruments 74S482 4-bit slice expandable control elements as the heart of the main processor. This processor is used in each subsystem of the link, and consists of two logic cards containing the necessary control and fiber optic interface logic required for the system. In addition to the processor, two other modules are required in order to complete the system; they are the 6681 DCC interface for the Central Computer side of the link and the V77-600 interface for the Centrifuge Crewstation Drive System. At this time, only the 6681 DCC interface has been completed. (Refer to Figure 47).

2.3.4.1.3 Firmware

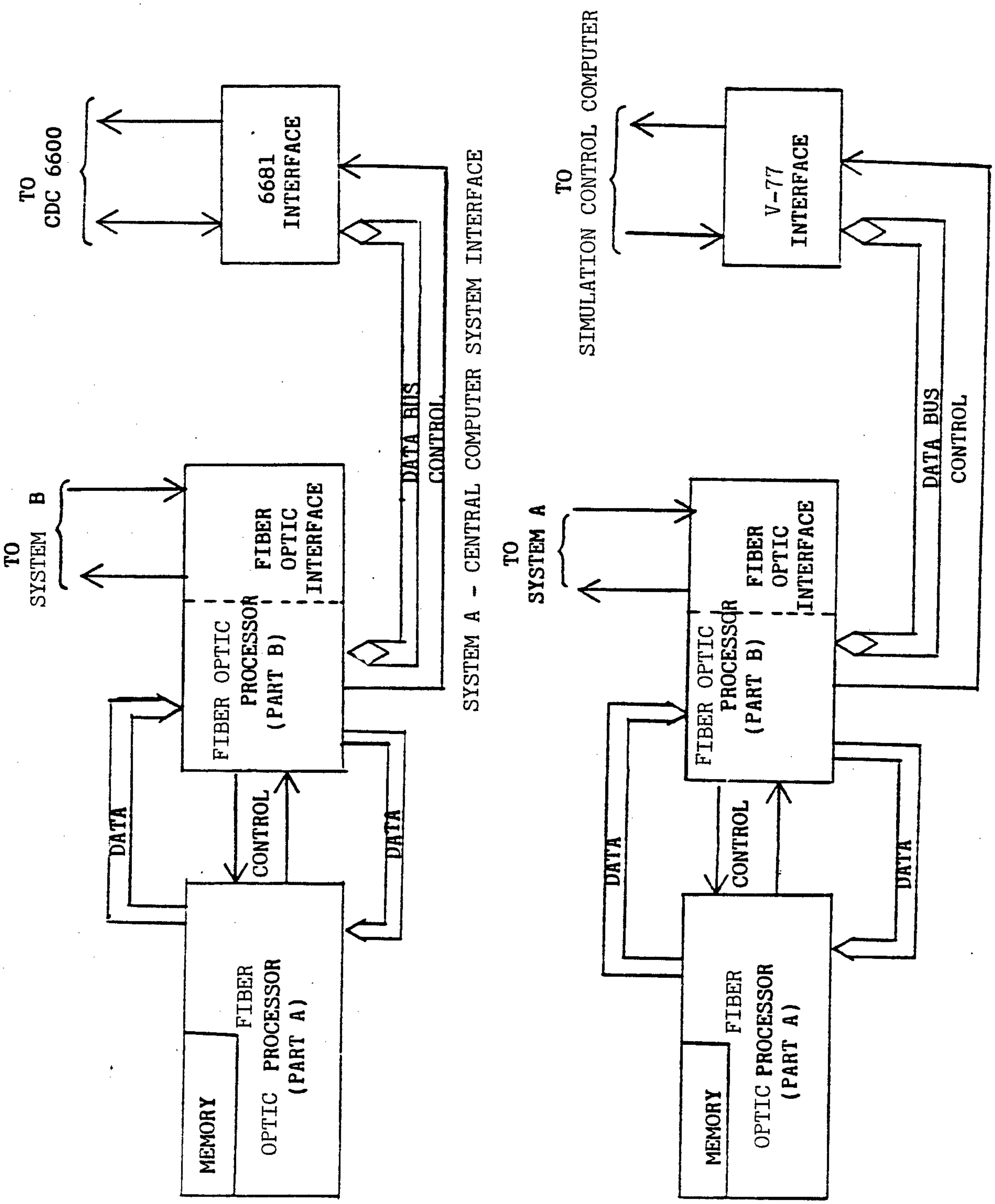
Firmware is required in order to make the Fiber Optic Link System operational. There are 22 instructions used to program the fiber optic processors. The instructions are listed in Table XXVIII. These micro-instructions are contained in PROM within the controller card. The firmware will control the transfer of data between the Simulation Control Computer and it's fiber optic interface, between the two fiber optic systems, and between the 6681 DCC and it's fiber optic interface.

2.3.5 Crewstation Drive/Gondola Equipment Interface System

The Crewstation Drive/Gondola Equipment Interface system (AREA 4), highlighted in Figure 48, consists of the centrifuge slip rings, a signal distribution system, a 1553B multiplexed data bus, a special purpose visual display interface, and interfaces between the Simulation Control Computer, the gondola J-Box, the Bio-medical Station and the Experiment Control Station. This section of the report provides detailed specifications and/or functional requirements for each component of this interface system.

2.3.5.1 Signal Distribution System

The signal distribution system is a system of cables with associated patch panels which are available to route signals, both analog and digital, from station to station. This system, illustrated in Figure 49 and detailed in Table XXIX will be described in the form of a diagram labeling each path, then a description of each individual path. The Instrumentation Station is an unmanned station where connections are made to the centrifuge slip rings. All Crewstation power requirements are met and routed from the Instrumentation Station. The three sets of centrifuge slip rings (Section 2.1.5) are included in the signal distribution system.



SYSTEM A - CENTRAL COMPUTER SYSTEM INTERFACE

SYSTEM B - SIMULATION CONTROL COMPUTER INTERFACE

FIGURE 47. **DETAILED BLOCK DIAGRAM OF FIBER OPTIC DATA LINK SYSTEM**

TABLE XXVIII

FIBER OPTIC PROCESSOR MICRO-INSTRUCTIONS

BPRU	Branch Positive Relative Unconditional to Address
BPRT	Branch Positive on True
BPRF	Branch Positive Relative to Address on False
BMRU	Branch Minus Unconditional
BMRT	Branch Minus on True
BMRF	Branch Minus on False
BAU	Branch Absolute Unconditional
BAT	Branch Absolute on True
BAF	Branch Absolute on False
BSU	Branch to Subroutine Unconditional
BST	Branch to Subroutine on True
BSF	Branch to Subroutine on False
RTU	Return Unconditional
RTT	Return from Subroutine on True
RTF	Return from Subroutine on False
PSU	Pause Unconditional
PST	Pause Until True
PSF	Pause Until False
LDR	Load 4-Bit Control Register
LDI	Load 4-Bits Immediate
VBR	Vector Branch
NP	No Operation

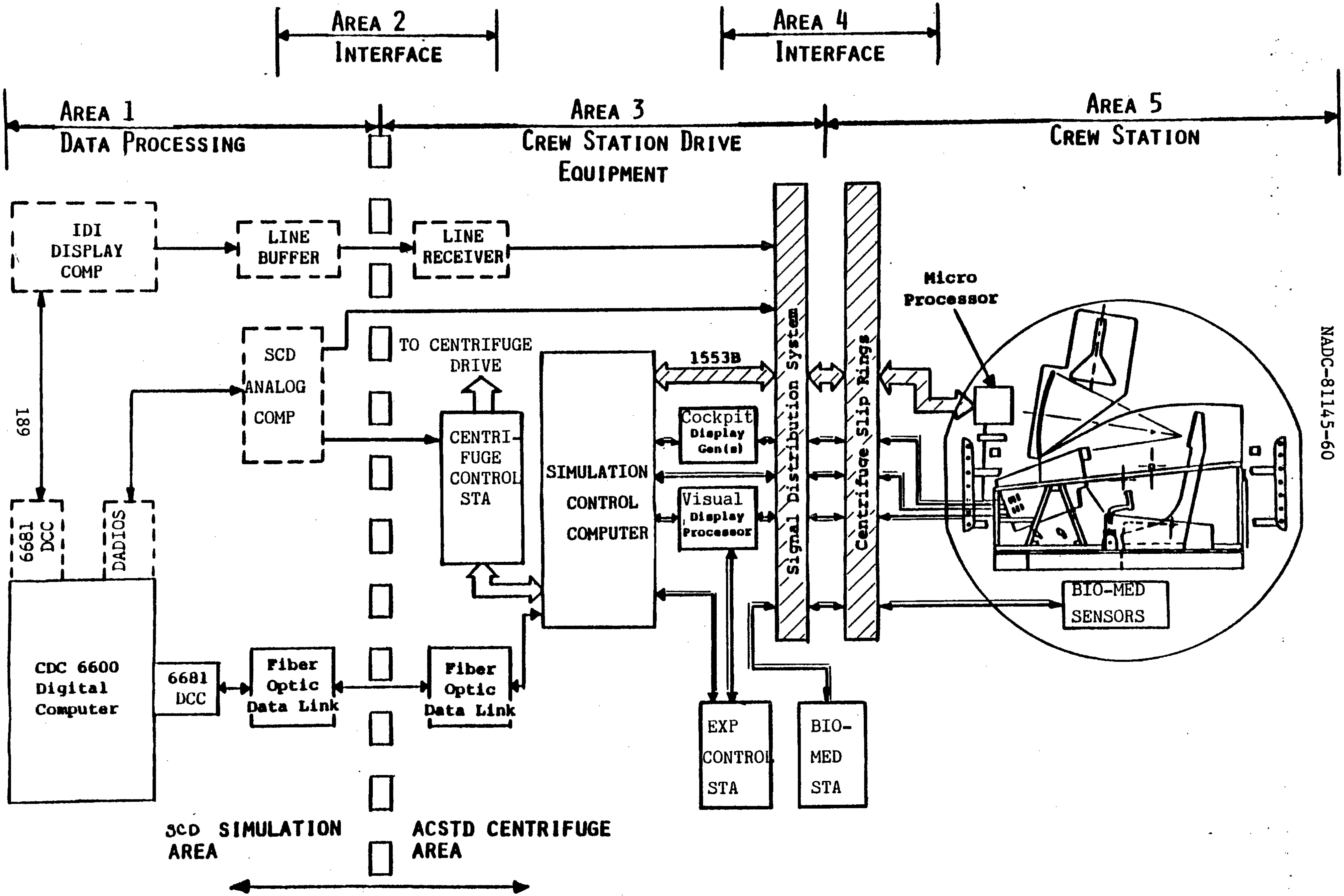


FIGURE 48. DFS CREWSTATION DRIVE/CREWSTATION INTERFACE EQUIPMENT (AREA 4)

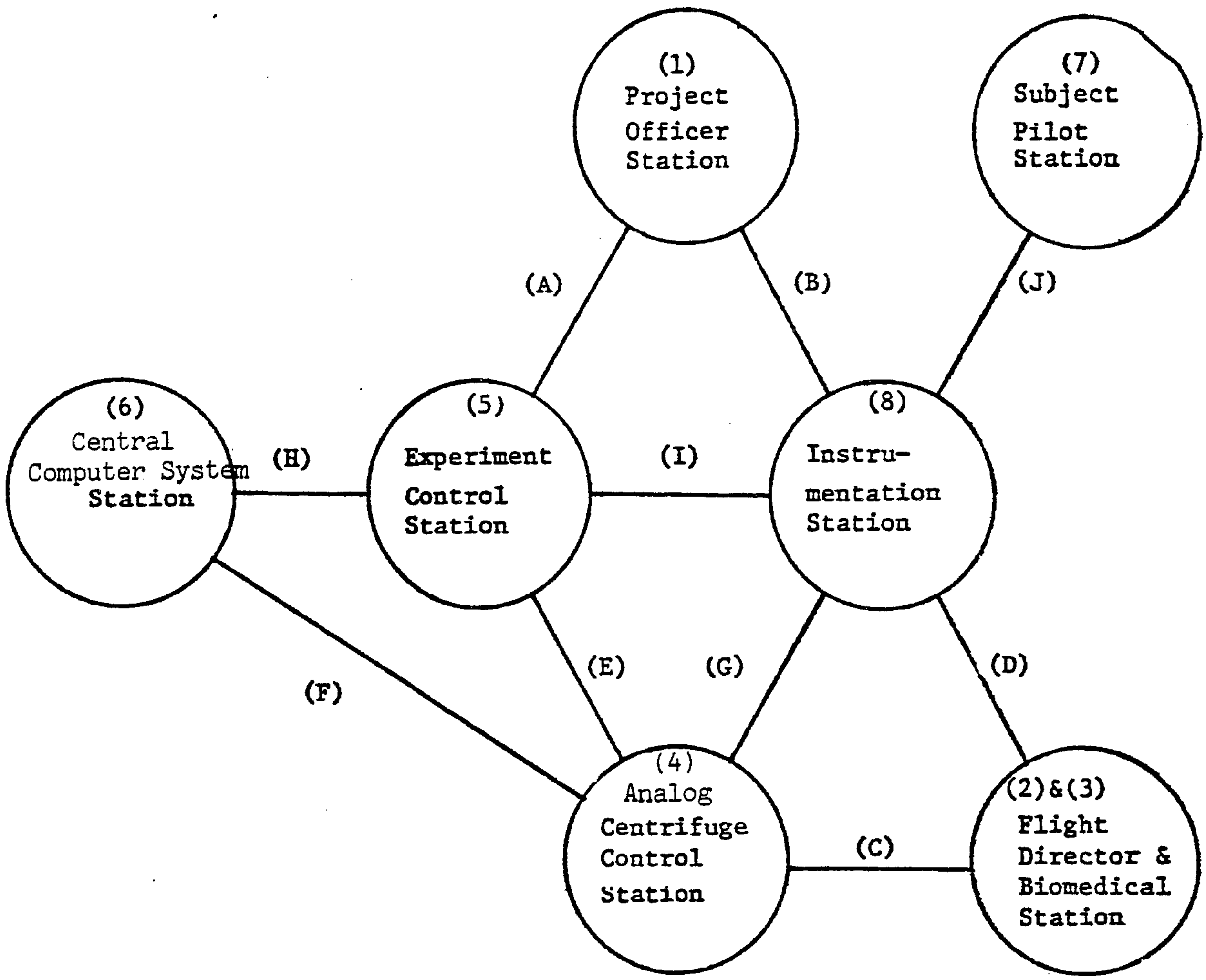


Figure 49. Signal Distribution System Cable Paths

TABLE XXIX. Signal Distribution System Cable Path Descriptions

(A) This path connects the Project Officer Station and the Experiment Control Station. It includes:
- 12 coaxial lines in one Alpha #2456 cable (95 ohms)

(B) This path connects the Project Officer Station and the Instrumentation Station. It includes:
- 20 shielded twisted pairs (#20AWG)

(C) This path connects the Flight Director/Biomedical Station and the Analog Centrifuge Control Station. It includes:
- 50 shielded twisted pairs (#20AWG)

(D) This path connects the Flight Director/Biomedical Station and the Instrumentation Station. It includes:
- 20 shielded twisted pairs (#20AWG)

(E) This path connects the Experiment Control Station and the Analog Centrifuge Control Station. It includes:
- 12 coaxial lines in one Alpha #2456 cable (95 ohms)
- 27 shielded twisted pairs in one Alpha #6022 cable (#24AWG)

(F) This path connects the CCS (Central Computer System) Station and the Analog Centrifuge Control Station. It includes:
- 27 shielded twisted pairs in one Alpha #6022 cable (#24AWG)

(G) This path connects the Analog Centrifuge Control Station and the Instrumentation Station. It includes:
- 100 shielded twisted pairs (#20AWG)

(H) This path connects the CCS Station and the Experiment Control Station. It includes:
- 8 twinaxial cables (RG22B/U, 95 ohms)
- 24 coaxial lines in one Alpha #3456 cable (95 ohms)
- 27 shielded twisted pairs in one Alpha #6022 cable (#24AWG)
- 2 fiber Optic cables (Galite 5000D-73)

(I) This path connects the Instrumentation Station and the Experiment Control Station. It includes:
- 18 twinaxial cables (RG22B/U, 95 ohms)
- 24 coaxial lines in one Alpha #2456 cable (95 ohms)
- 27 shielded twisted pairs in one Alpha #6022 cable (#24AWG)

(J) This path connects the Instrumentation Station and the Subject Pilot Station. This path includes the three sets of centrifuge slip rings and the following:
- 19 coaxial cables (RG59B/U & RG187A/U, 75 ohms)
- 48 shielded twisted pairs (#18AWG & #20AWG, 5 amp rings)
- 26 shielded twisted pairs (#20AWG & #22AWG, 1 amp rings)
- 15 individually shielded wires (#20AWG & #22AWG, 1 amp rings)
- 16 15-amp rings and wiring for power

2.3.5.2 Centrifuge Slip Ring Interface

The centrifuge slip ring complement of wires are detailed in section 2.1.5 of this report. The utilization of this wiring complement is described in section 2.3.3.10 of this report. The slip ring complement of wires is part of the existing Dynamic Flight Simulator facility and therefore the equipment that will utilize these slip rings must be made compatible with it. One potential problem area is the simulated real-world display resolution. The equipment resolution specification (5 arc mins) is based on a normal simulation facility setup. Noise filters might have to be applied to the display unit input lines, to produce the required resolution.

2.3.5.3 Visual Display Processor Interface

The SP2 Visual Display Processor requires an interface with the Simulation Control Computer (1), the SP2 Visual Display Unit (2), and the Experiment Control Station (3), illustrated in Figure 48. The visual display unit/display processor interface (2) requires 6 coax slip rings for each display unit (3 video, 1 unblank, 1 focus, 1 X-Y deflection). The display unit lines can be connected in the gondola J-Box. The display unit requires a power supply to provide the required voltages. The power supply requires a 230V AC, 60 Hz input which can be obtained in the J-Box.

The Visual Display Processor interfaces the host simulator computer (1) (Simulation Control computer) through the E2832 Buffered I/O controller card. The CDC 6600 Digital computer will provide aircraft position and altitude data to the visual display processor through the Simulation Control Computer. Visual system control data will be provided directly from the Simulation Control Computer.

The Experiment Control station interfaces with the visual display processor (3) to provide a facility for keyboard entry such as generating new scene/target images, and controlling and monitoring the scene. This interface will be described in Section 2.3.5.8.

2.3.5.4 Symbol Generator System Interface

The Symbol Generator System requires an SCC Interface Card (6). This card will be procured as part of the Symbol Generator Procurement. The Symbol Generator System will interface the cockpit and HUD Display units through the Cockpit/Microprocessor J-Box System (7) described in Section 2.3.3.10.

2.3.5.5. SECS-80 Microprocessor Interface (1553 Bus)

The interface between the Simulation Control computer and the SECS-80 micro processor is through a standard 1553B Multiplex Data. The 1553 Bus will be utilized to transfer indiscrete and outdiscrete signals, and D/A and A/D signals.

The MIL-STD 1553B Bus provides the capability of handling the digital signal multiplexing required in particular for the Dynamic Flight Simulator because of the limited number of gondola slip ring wiring lines. The signal information is transferred in a digital serial format at a high speed (1 million bits per sec) and low error rate. Up to 31 terminals can be tied to the single signal conductor or data bus. Messages on the data bus are usually groups of 16 bit words, where each word is preceded by an appropriate 3-bit time synchronization and appended with a parity bit, for a total of 20 bits. Maximum data transfer rate over the bus is approximately 48K data words per second. A bus controller directs signal traffic on the bus by issuing command words containing the address of the terminal commanded to listen to data on the bus, or to transmit data on the bus. The bus controller will be the Simulation Control Computer.

A Simulation Control Computer/1553 Bus Interface (4) is required to provide the compatibility of the 1553 Bus line with the V-77 Computer. This interface will be built using a parallel interface from the V-77 Computer to an Intel 8085 microprocessor with a 1553 Bus interface card on the front end of the microprocessor.

A SECS 80/1553 Interface card (5) will be utilized to provide the compatibility of the 1553B Bus line with the SECS 80 Microprocessor. This card is an off-the-shelf item compatible with military specifications, weighing less than 40 ounces, with overall dimensions of 6 inches length by 9 inches width by 3/4 inch height. The Equipment Specification SECS 80/1553 interface card for the 1553 Bus is provided in reference (o).

2.3.5.6 Gondola J-Box Interface

The gondola J-Box is described in section 2.3.3.10 of this report. Interconnection between the J-Box and the centrifuge slip rings is accomplished through the power and signal panels located in the centrifuge band utilizing the wiring complements detailed in Section 2.1.5.

2.3.5.7 Biomedical Station Interfaces

The Biomedical Station is described in section 2.3.2.5 of this report. This station and the required interfaces currently exist as part of the Centrifuge Facility (Bldg 70).

2.3.5.8 Experiment Control Station Interfaces

The Experiment Control Station interfaces both the Visual Display System and the Simulation Control Computer.

The Visual Display System equipment required in the Experiment Control Station includes a scene controller, a scene TV monitor and a KSR 820 Teletype Input System. The required equipment interfaces will be supplied as a part of the Visual Display System contract.

The Simulation Control Computer equipment required in the Experiment Control Station includes a Diablo System Inc. Model 1620 Teletype input system, and a CRT/Teletype input system. These input systems will be obtained as a part of the Simulation Control Computer Procurement.

2.3.5.9 Analog Centrifuge Control Station Interfaces

The Analog Centrifuge Control Station interfaces the Simulation Control Computer through an Analogic Model AN5400 analog interface which has been provided as a part of the Simulation Control Computer procurement.

2.4 DYNAMIC FLIGHT SIMULATOR SYSTEM SOFTWARE DESCRIPTION

2.4.1 Central Computer System Data Processing

2.4.1.1 Simulator Software Implementation

The majority of the software for the F-14 spin simulation will be developed using thé batch and real-time capability of the NAVAIRDEVCEN Central Computer System (CCS), which utilizes the Control Data Corporation (CDC) 6600 Digital Computer. The software implementation will include models of the F-14 aircraft, the real-world environment, and the centrifuge drive algorithm. The Aircraft and Crew Systems Technology Directorate (ACSTD) V77-600 minicomputer will be used as the Simulation Control Computer (SCC) for the DFS handling all communication between all peripherals in the centrifuge area and the CCS.

The simulation software program shall be implemented by the contractor in a systematic top-down method conforming to SCD real-time simulation standards and procedures. The software tasks can basically be broken down into functional subtasks. These subtasks are: software architecture, coding and compiling, module test and debug, and software integration and verification. Before any significant amount of work can be completed on the software, the math models, data collection requirements and the experimental design must be clearly and completely identified.

2.4.1.1.1 Software Architecture

This process, in the broad sense, is the translation of simulator software requirements to detailed flowcharts suitable for programming including the following:

- o The review/analysis of all the simulation models to be implemented,

- o The upper level functional flow indicating the architecture of the simulation software. This includes the partitioning of the software between the CCS and the SCC, the identification of all the software modules, the order in which the modules are called and the segmentation into the various interrupt loops.

- o The identification of the intermodule I/O data and communication methods, and the identification of the standard and special I/O requirements. This includes, but is not limited to, standard real-time hybrid I/O; special purpose I/O, whether synchronous or asynchronous; and standard I/O to/from magnetic tape, hard copy devices, auxiliary storage and rotating mass storage.

- o The identification of the procedure to be used for naming global and local program variables, methods of initialization, formats and data storage. This includes, but is not limited to, the definition of flag words, pointers, simple/subscripted variables, integer/real type, and other variables and constants.

- The identification of the calculation precision/accuracy required to provide solutions which are within the specified error tolerances of the simulator, such as methods of numerical integration, curve fitting techniques, table look-up methods, and implicit solution methods.

- An estimation of the memory and timing requirements of individual modules and interrupt segments.

- The identification and definition of testing standards.

- Detailed defining flow charts; formal documentation will not be required.

It is appropriate to have a critical design review or structured walkthrough before entering the next phase, coding and compiling.

2.4.1.1.2 Coding and Compiling Process

This process encompasses the translation of the software architecture to top-down-structured code and the successful compilation of single modules.

- The coding and comments of the software in a format consistent with the SCD PROFILE processor, or its equivalent.

- The punching and verification of the card deck.

- The compiling or assembly of the individual modules to identify and correct errors: e.g., misspelled variables, illegal expressions, undefined statement labels, syntax errors, and variables which are referenced but undefined.

2.4.1.1.3 Module Test and Debug Process

This process reduces or eliminates the number of errors in each module by use of test software.

- Writing a driver test program providing all necessary input data to the module and converting the output to computer printout.

- Comparing the actual module outputs with the expected ones.

2.4.1.1.4 Software Integration and Test Process

This process integrates all modules into a single program, executes and performs controlled tests.

- The loading of all simulation modules and the linking of all subroutine and interrupt segments.

- The execution of the entire simulation using nominal initial conditions and controlled tests of specific fuctions. Examples of this include: the sequence of man-machine interactions required to change operation modes, verify that the correct display information/symbology is presented for a given set of switch positions/keyboard entry, and I/O interface tests to insure that data flowing to/from the external devices is of the correct format, refreshed at the proper rate and has reasonable values.

- The execution of the entire simulation program under a controlled scenario. This can vary from static/dynamic checkout of the aircraft model to "flying" the entire mission.

2.4.1.1.5 SCD Standards and Procedures

The contractor shall conform to SCD programming and documentation standards and procedures so as to provide visibility to the Government over the software implementation process and computer resources utilized.

2.4.1.1.5.1 Programming

The Spin Simulation software will consist of many subroutines written in FORTRAN. Portions of the following havebeen excerpted from reference (p). The guidelines which have been established concering the development of this software are: that all FORTRAN code will be written in top-down structured format, and will be sufficiently commented to adequately explain its functional procedures. The benefits of the top-down structured programming have been demonstrated, but a serious limitation is encountered if it becomes necessary to modify the logic of the code. Any addition or deletion of logic will result in incorrect indenture in the top-down structured format, necessitating an edit of all affected code to correct the indenture level.

Changes in program logic have the same effect on flowcharts as they do on the structured code, since portions of an existing flowchart may need to be completely redrawn to reflect the changes.

The following support software is available in-house as part of the CDC 6600 library:

- A profile processor that will produce "flow profiles" directly from the commented FORTRAN code. Thus, when a routine is coded, there will be no need to draw boxes, lines, arrows and other time-consuming flowcharting aids. The flowchart will be essentially constructed and documented along with the code.

- An editor that will eliminate the need for repunching numerous cards when logic changes are made to a routine. Also, by processing edited code with the profile processor, updated profiles are automatically produced, eliminating the need for patching or redrawing flowcharts which have been modified.

It is recommended that these support software packages, or their equivalent, be used in the implementation of the spin simulation software resident in the CCS.

2.4.1.1.5.1.1 Profile Processor

Top-down structured code produces, in essence, a logic "profile" of a program. By commenting the FORTRAN code in a predefined manner, the comments themselves can be utilized to describe the program logic in a top-down structured form. By extracting the comments from the source code, a profile can be constructed consisting of ordinary English phrases and utilizing the IF, THEN, ELSE and DOWHILE logical constructs with nesting levels clearly delimited.

The processor will ignore blank comment cards and comment cards with the character "-" in column 2. This allows the user to offset comments with blank comment cards and to use informative comments which would not necessarily be used in the logic profile.

The processor connects IF-ENDIF and DOWHILE-ENDDO constructs with a series of dots which clearly define nesting levels. Since the spacing between nesting levels can vary for different routines, the dot spacing can be input as a substitution parameter on the LGO card.

Comment Formats

(1) All IF statements must be preceded by an IF comment beginning in the same column as the IF statement, and followed with the comment THEN. The THEN comment should be indented from the IF comment by a number of spaces which are less than the nesting level spacing. The IF comments will, in effect, negate the IF statement in order to insure that the comment will read properly.

Example: An IF statement that reads

```
IF(MODE.EQ.1)GOTO 100
```

will be commented as follows

```
C      IF MODE IS NOT OPERATE
       IF (MODE.EQ.1)GOTO 100

C         THEN
```

(2) The code immediately following the THEN comment must be commented with either an explanation of the THEN portion of the code or with another IF comment.

Example 1:

```
C     IF MODE IS NOT OPERATE
      IF(MODE.EQ.1)GOTO 100
         THEN
C          BEGIN HOLD PROCEDURE
           IHOLD = 1
```

Example 2:

```
C     IF MODE IS NOT OPERATE
      IF(MODE.EQ.1)GOTO 100
C        THEN
C          IF MODE IS NOT HOLD
           IF(MODE.EQ.2)GOTO 100
C        THEN
```

(3) An ELSE comment must begin in the same column as the THEN comment. The code immediately following the ELSE comment must be commented with either an explanation of the ELSE portion of the code or with another IF comment. An ENDIF comment must be placed at the end of the IF operation in the same column as the IF comment.

Example 1:

```
C     IF MODE IS NOT OPERATE
      IF(MODE.EQ.1)GOTO 100
C        THEN
C          BEGIN HOLD PROCEDURE
           IHOLD = 1
           GOTO 110
         ELSE
C          SET OPERATION INDICATOR
 100       INDOP = 1
 110  CONTINUE
C     ENDIF
```

Example 2:

```
C     IF MODE IS NOT OPERATE
      IF(MODE.EQ.1)GOTO 100
C        THEN
C          BEGIN HOLD PROCEDURE
           IHOLD = 4
           GOTO 130
         ELSE
C          IF ERROR FLAG IS NOT SET
 100       IF(IERR.EQ.1)GOTO 110
C            THEN
```

```
C              SET OPERATION INDICATOR
               INDOP = 1
               GOTO 120
             ELSE
C              ISSUE ERROR MESSAGE AND EXIT
 110           CALL MSSG (IMSG)
               IEXIT = 1
 120         CONTINUE
C            ENDIF
 130 CONTINUE
C    ENDIF
```

(4) Do loops should be connected with DOWHILE or DO UNTIL comments which explain the function of the loop. The end of a DO loop is commented with an ENDDO comment.

Example:

```
C     DO UNTIL FLAG WORDS ARE INITIALIZED
      DO 100 I = 1, 10
           IFLAG(I) = 0
100   CONTINUE
C     ENDDO
```

(5) Computed GOTO statements are commented using the CASE comment. This comment should contain a description of the case condition. The end of the case function is commented with an ENDCASE comment.

Example:

```
C     CASE MODE VALUE (IMODE)
      GOTO(100,200,300)IMODE
C         *IMODE EQ1
C         HOLD MODE
 100      IHOLD = 1
          GOTO 400
C         *IMODE EQ2
C         RUN MODE
 200      IRUN = 1
          GOTO 400
C         *IMODE EQ3
C         IC MODE
 300      IIC = 1
 400 CONTINUE
C     ENDCASE
```

(6) An abstract should be inculded in the beginning of the routine. The comment ABSTRACT, if included, must be the first non-blank comment, and begin in column 7. Following the text of the abstract, the comment END OF ABSTRACT.

2.4.1.1.5.1.2 Editor

The editor is a processor which performs insertion, deletion, and shifting of source code contained on a specified file (TAPE1). Edit directives are placed in the input stream and changes are effected by referencing appropriate line numbers in the source code. The line numbers can be obtained from a compilation listing of the program to be edited. Insertions, deletions and shifts can be performed in any order.

While shifting, the editor automatically forms continuation cards for any lines which are shifted past column 72. The continuation cards are also properly indented and begin at a logical breakpoint; that is, variable names are not broken over two lines.

A copy of the edited source code is written on a file and this file can be used as input for a compilation or an UPDATE run.

2.4.1.1.5.2 Documentation

Good software documentation practices are important to the generation of any moderate to large simulation effort because it results in a better quality product. It serves as an aid to the thought process, improves communication between software team members, is a vehicle for review and modification, and facilitates the introduction of new personnel to the software team. The DFS software documentation will be divided into: (1) documents describing the development of the software resident and operating in the CCS and V77-600 minicomputer, (2) the I/O between these computers and the various peripherals; and (3) communication inherent with top-down-structured code, including in-line comments and header information.

2.4.1.1.5.2.1 Software Architecture and Operation Documents

These documents should include, but not be limited to, the following:

1. Introduction/Overview

   Brief discussion of DFS configuration, function, coding philosophy and standards.

2. Functional Block Diagram

   Upper level functional block diagram showing real-time executive: background, run control, exit control, display control and termination control. In addition, off-line functions should be listed.

3. Real-Time System Interface

   a. Physical Layout

      (1) Common Layout

(a) Blank Common. Discusses CCS use of blank common and describes its loading into Central Memory (CM).

(b) Labeled Common. Discusses CCS use of labeled common and describes its loading into CM.

(2) Interrupts

(a) Structure. Describes Real-Time Interrupt and discusses the number and periods of the simulator interrupts. Interaction of the background program is also discussed.

(b) Purpose. Describes the general function of each simulator interrupt.

(3) Overlays

(a) Structure. Describes purpose, number and program flow of simulator overlays. This includes a graphic presentation of memory allocation to overlays, and methods of affecting this memory structure.

(b) ECS. Describes relationship of Extended Core Storage to Real-Time Overlays.

(c) Restrictions. Discusses DATA statements, local variables and interaction between Interrupts and Overlays (memory and subroutine conflicts).

(4) Subroutine Linkages

(a) Interrupts. Discusses process by which external references are satisfied by Real-Time Loader. This includes the use of dummy routines to reduce core requirements.

(b) Overlays. Discusses process by which external references are satisfied by the Loader. This includes methods of forcing linkages to desired locations.

b. Timing

(1) Relationship Between Interrupts. Discusses means by which central processor (CP) is shared by Interrupts. This includes effects on system performance due to interrupt switching.

(2) Timing for Each Interrupt. Defines Required Computer Time (RCT), including graphic representation of simulator CP usage.

c. External Devices

Discusses communication between the CDC 6600 and the following external devices:

(1) Direct Analog Discrete Input/Output System (DADIOS)

(2) Data Extraction. Discusses nature and number of mass storage devices accessed by the DFS.

(3) Displays. Discusses nature and number of display generation devices.

(4) Fiber Optic Data Link. Discusses DFS unique interface to the Simulation Control Computer.

4. Software Functional Description

a. Executive Control

(1) Background. Discusses functions performed in non-Real-Time such as: overlay setup, error recovery, real-time status monitoring.

(2) Real-Time System Linkage. Discusses control structures within interrupts.

(3) Mode Control. Discusses simulator operating modes.

b. I/O and Peripheral Devices

Describes the functional methods for simulator interface to the following devices:

(1) Analog Centrifuge Controller

(2) SP-2 Real-World Visual Display

(3) Graphics V77-600 Display Generation

(4) Cockpit.

c. Manned Stations

Discusses purpose, operator interface, data exchange, and automatic functions of the following:

(1) Project Officer Station

(2) Flight Director Station

(3) Biomedical Station

(4) Analog Centrifuge Control Station

(5) Experiment Control Station

(6) Central Computer System Station

(7) Subject Pilot Station

(8) Instrumentation Station

d. Utility Routines

Defines and discusses purpose of DFS utility software.

e. Data Structure

(1) Common. Discusses ordering restrictions and variable allocation to the following types of common:

(a) Blank
(b) Labeled
(c) ECS

(2) Constants. Discusses constants available to all simulator functions.

(3) Buffers/Data-Base. Discusses requirements and methods of use.

f. Operational Software

Discusses the set of computer programs which integrates the man and the simulation hardware, and enables the resultant man-machine system to fulfill its mission requirements.

g. Test Software

Discusses other programs used during equipment acceptance, module test, subsystem/system integration and validation testing.

h. Support Software

Discusses other programs used in support of the simulator for data reduction, hardware diagnostic and configuration management.

5. Appendices

a. External Device Word and Bit Assignment

b. Common Layout

c. Dictionary Listing. An alphabetical listing including units, limits, definition and physical symbols for the following:

(1) Variables

(2) Constants

(3) Flags

(4) Tables

(5) Indexes

d. <u>Profile Listing</u>.

2.4.1.1.5.2.2 <u>Detailed Coding Documentation</u>

In addition to the comments inherent in the top-down structured code, each subroutine will contain the following HEADER information:

1. Project Identification
2. Subroutine "NAME"
3. Abstract
4. References
5. Modification History
6. List of Inputs and Outputs

    INPUT

    Variable Name - definition

    OUTPUT

    Variable Name - definition

7. Interface Relationship

SUB A		SUB D
SUB B	"NAME"	SUB E
SUB C		SUB F

2.4.1.2 <u>Operational Software</u>

The following sections will describe the major software modules required for the DFS. Primarily they are updated versions of an ACM simulation file which modeled an F-14 and threat aircraft and was utilized to investigate one-on-one air combat tactics, weapons systems, and helmet mounted sights. To form a baseline DFS spin simulation file, all modules associated with the threat aircraft, both weapon systems, and data collection were deleted. The resultant file represents only the F-14 aircraft and the real-time executive portion of the ACM. Analysis may determine that it is more cost effective in terms of flexibility, efficiency, and accuracy, to use only selected baseline routines while totally redesigning others. These determinations shall be made by NAVAIRDEVCEN cognizant engineers.

2.4.1.2.1 Real-Time Executive

The DFS time-critical simulation demands a response within a fixed time after it has received an interrupt. The CDC 6600 provides guaranteed processing of all interrupts through system hardware and/or software monitors and schedulers. Once the interrupt is sensed, the system captures all data needed to process the task, performs the processing, and has the results available within the required time. The real-time executive design will define and partition the time-critical and non-time-critical (background) tasks and logic. The executive will consider various simulator configurations including number of stations, operator functions, hardware-to-program interfaces; experiment design and data collection/reduction and off-line analysis.

The current spin simulation baseline executive reflects the ACM version and is for local control at the CCS only. The DFS executive shall, reflect all the tasks required for a manned centrifuge run controlled at the Centrifuge Area (Bldg 70).

2.4.1.2.2 Peripheral Processor (PP) Program

In addition to the CCS central processing capability, the system has a number of PPUs (Peripheral Processor Units). Each PPU is a general purpose, 12-bit word length computer with 4K of memory. The PPUs communicate directly with central memory and all data channels, enabling all I/O operations, hybrid control and data transfer to be performed without the CPU (central processor unit), thus significantly reducing the CPU overhead and leaving it free to perform job processing. The PP software is written in assembly language.

The PP software in the DFS configuration shall control the I/O between the CCS and the Simulator Control Computer, via the CDC 6681 DCC (Data Channel Converter) and the fiber optic data link.

2.4.1.2.3 F-14 Aerodynamic Data

The ACM aerodynamic data package represents low angle-of-attack linear coefficients. The spin simulation requires high (AOA) angle-of-attack linear and non-linear data, and force and moment equations consistent with modeling fully developed spins. Given these requirements, reference (m) documents the redesign of the ACM simulation in these areas. (See also Section 2.2)

The DFS aerodynamic data package will be resident on a CCS permanent file in a packed format of at least four values per 6600 word. The file shall be structured to allow direct loading of data into blank common and will be utilized by the existing ACM table look-up routines, or their equivalent, to satisfy all spin simulation function generation requirements.

The ACM table look-up routines are set up to handle functions of up to three variables; however, the capability exists to handle functions of up to five variables. The data package resident in the ACM baseline file represents the outdated F-14 linear coefficients. The high AOA aerodynamic data

described in reference (m) shall be generated. The process used to generate this data, whether the ACM methodology or its equivalent will be determined from an analysis of ACM documentation and ref. (m). In any case, this task represents a significant amount of effort. If a new design is determined to be the best way to go, it must be carefully documented. If the ACM method is used, the following steps are suggested:

1. If the coefficient is not in body-axes it shall be transferred to body-axes off-line.

2. Determine the breakpoints for the independent variables; three regions are allowed for each independent variable. It may be advantageous to plot the functions as given in ref. (m) to optimize the fit; these plots would also serve as a baseline for validation and are easier to envision than tabulated data.

3. Tabulate data; dependent and independent on FORTRAN coding sheets in format required by Program AERODAT.

4. Keypunch and verify.

5. Run Programs AERODAT and DATPACK to produce unpacked and packed data files.

    (a) AERODAT places unpacked function data on a permanent file. The data on this file can be used by other support software programs such as: AEROPLT, generate function plots; PUNCH, punches data deck; and a digital check program that will be modified for the DFS.

    (b) DATPACK takes unpacked data from the permanent file created by AERODAT, processes the data for use by the function generation routines, and puts it out on a permanent file for loading by the real-time program.

6. Run CALCOMP plotting program to identify and correct bad points.

7. Validate data package.

2.4.1.2.4 F-14 Aircraft System Modules

2.4.1.2.4.1 Flight Control System Modules

The ACM simulation of the F-14 primary control system and SAS (Stability Augmentation System) was implemented by hybrid/analog techniques on the SCD EAI 8800 machines. For the DFS, a digital control system shall be implemented. This method offers some attractive features when compared to the hybrid/analog solution: it permits a more rapid changeover between aircraft, is more repeatable, and is easier to maintain.

A description of the control system in terms of differential tail, stabilator, rudder and spoiler deflections, and a method of implementation is contained in ref. (m). The tasks for this module include:

(1) The review of ref. (m) to gain familiarity with the four control systems and the method of implementation.

(2) If the review suggests a different or modified algorithm and/or method of implementation, it must be justified to the satisfaction of a NAVAIRDEVCEN cognizant engineer.

(3) The model shall be implemented, validated and documented.

2.4.1.2.4.1.1 Stick/Rudder Control Loader Module

This system is used to simulate the F-14 "feel" for stick and rudder pedals through potentiometers, switches, and function generators. External force signals, such as the longitudinal Mach schedule, shall be programmed.

2.4.1.2.4.1.2 Engine Module

Engine module modifications will include individual thrust response to throttle command, total inlet temperature, RPM, and flame-out capability.

2.4.1.2.4.1.3 Flaps Module

The subroutine named FLAPS in the ACM baseline file generates the flap/glove-vane deflection rates as a function of pilot command. The module also generates blow-back of flaps/glove-vane.

The DFS force and moment equations and aerodynamic data as described in ref. (m) contain implicit flaps and slats data corresponding to automatic deflection of maneuvering flaps to 10 degrees and slats to 8.5 degrees. The detailed Experiment Definition Phase (Section 1.5) will determine if these ranges are adequate for the experiment profile and if manual override is required, implementation and validation of the digital model will follow.

2.4.1.2.4.1.4 Speedbrake Module

Speedbrake deflection was implemented by hybrid/analog techniques during the ACM simulation. It was beep-controllable by pilot manipulation of throttle mounted EXTEND and RETRACT switch. A blow-back capability was provided during afterburner flight.

The DFS F-14 requirements for speedbrake control and blowback capability will be determined, followed by the implementation and validation of the digital model.

2.4.1.2.4.1.5 Wingsweep Module

During the ACM simulation optimum wingsweep was assumed and a schedule was generated to drive the wingsweep indicator. The DFS requirements may require the capability of manual wingsweep override. If this feature is deemed necessary it will require the generation of high AOA data for various wingsweep deflection angles. At the present time this approach is not planned.

2.4.1.2.4.2 Cockpit Instruments Module

The Cockpit Instrumentation is defined in Section 2.3.3.7 and the Signal Range Data is documented in Section 2.3.3.12. The software will include the generation of digital outputs to the D/A converters.

2.4.1.2.4.3 Panels, Switches and Indicator Lights Module

The Panels, Switches and Indicator Lights are defined in Section 2.3.3.8 and the signal/voltage information is documented in Section 2.3.3.12. The software will include the interpreting of indiscretes and the generation of outdiscretes as required by the Crewstation equipment.

2.4.1.2.5 Equations of Motion

As part of the development of the DFS, an analysis was completed which led to the update of the ACM 6 degree-of-freedom linear coefficients to non-linear high angle-of-attack equations of motion, suitable to model fully developed spins. These modifications are described in ref. (m).

The software task will include the review of ref. (m) and the ACM simulation documentation to determine if any modules are usable and the implementation and validation of the equations of motion.

2.4.1.2.6 Quaternion Transformation/Integration Techniques

While continuous rotation represents no problem in the real world, it does introduce discontinuities in simulations using Euler transformation. The use of quaternions avoids the singularities of Euler transformation, and produces a more efficient set of equations than direction cosines; therefore, quaternions were utilized in the ACM simulation. The following integration methods were used during ACM: Euler, in the 100 ms loop; and Adams-Bashforth, Taylor and Euler in the 50 ms loop.

Quaternion transformations will be used in the DFS. In addition, the contractor shall implement the methods of integration as defined by the NAVAIRDEVCEN cognizant engineer.

2.4.1.2.7 Centrifuge Drive Algorithm

Methods of centrifuge control will be investigated for greater fidelity and efficiency. This investigation will result in a centrifuge drive algorithm design that will produce the correct acceleration as perceived by the pilot, with minimum angular "artifacts."

This module is unique to the DFS configuration. The task will be to implement the algorithm in the real-time file, test and validate.

2.4.1.2.8 Miscellaneous Modules

The following sections describe the remaining known software modules.

2.4.1.2.8.1 Data Collection Module

The data collection preliminary requirements include: eight strip-chart channels, 32 variables to magnetic tape, and eight variables displayed at the Experiment Control Station via PIO. Data rates and variable identification will be determined by the NAVAIRDEVCEN cognizant engineer.

2.4.1.2.8.2 Buffet Module

The DFS cockpit/crewstation has a vertical axis, hydraulically actuated buffet system. The requirements call for buffet intensity as a function of angle-of-attack. Buffet due to velocity is not considered since the aircraft is expected to operate below the transonic region.

This software task requires the finalization of the requirements, programming, test, and validation.

2.4.1.2.8.3 Aircraft Trim Module

There is a requirement that the aircraft be "controllable" and not in a state of departure at the start of real-time operation. Also, the simulation must achieve a condition close to trim automatically during the initial condition or experiment set-up phase.

The ACM simulation had an elaborate trim procedure where the pilot manually trimmed the aircraft before each run using the longitudinal stick and the throttle. The TRIM software module calculated "thrust" and "pitch" errors used to drive a cross-hair instrument in the cockpit.

The DFS will have the capability to automatically trim the aircraft to straight and level flight before each simulator run.

2.4.1.2.9 System Integration and Validation

The integration and validation phase encompasses the integration of all software and hardware into the simulator and the performance of tests to "validate" the correct operation of the hardware-software system. The following sections shall primarily discuss the validation of the F-14 aerodynamic model and the centrifuge drive algorithms. A major portion of the software will be validated during integration of the software modules; e.g., programmed Input/Output (PIO), data collection, interrupts, etc.

2.4.1.2.9.1 Aircraft Model Validation

This task includes the generation of a validation plan and supplying of any flight test data for comparison checks. During validation of the aircraft model for the DFS, the following types of tests will be performed: static check of aerodynamic data, dynamic check of control system and SAS, and flight test comparison checks.

2.4.1.2.9.1.1 Static Check

For given initial conditions aircraft force, moments and aerodynamic coefficients will be precalculated. Data will be collected in the static mode and compared to the precalculated data.

2.4.1.2.9.1.2 Control System Dynamic Check

Step and sinusoidal inputs will be imposed on isolated networks of the DFS control system. The input and output will be recorded on strip charts and the responses were examined for proper gain and phase.

2.4.1.2.9.1.3 Flight Test Comparison Checks

Flight comparison checks can be performed with a man-in-the-loop or via digital inputs/control. The simulator will be flown through the same maneuvers as the flight test aircraft and simulation time histories compared to flight test data. The following checks have been identified from previous simulations:

- Static longitudinal stability; acceleration-deceleration and deceleration-acceleration profiles using throttle holding constant altitude and wings level.

- Dynamic longitudinal stability; force doublet at stick from various trim conditions.

- Maneuvering longitudinal stability; windup turn

- Static lateral stability; steady heading sideslip

- o Dynamic lateral stability; rudder pedal doublet

- o Roll performance; full stick authority, rudder pedals free, SAS on, 360-degree rolls

- o Deceleration device performance; cut power to idle and extend speedbrakes simultaneously.

2.4.1.2.9.2 Centrifuge Drive Algorithm Checkout

The centrifuge drive algorithm software shall be implemented and integrated into the DFS Spin file. Test procedures and validation plan shall be developed and supported for algorithm checkout.

2.4.1.2.10 Test Data Analysis, Reduction, and Replay

Software shall be provided for experimental test data analysis, reduction, replay, and quick-look capability. The software shall provide a means to review the progress of an experiment. Using the analysis and reduction software, the human factor aspect of an experiment may be subjected to scrutiny in conjunction with the dynamics of the experiment. Time tagged data shall be tabulated and written to hardcopy, either a listing or to a magnetic external storage medium.

Software resident on the SCC shall be capable of running static and dynamic "replays" using data collected during an experimental run. Static replay shall consist of driving the instruments in the gondola and the graphics displays while leaving the centrifuge at rest. A replay in this mode may have the option of altering the rate of replay. The replay may be run at normal speed, accelerated, decelerated, or frozen.

A dynamic replay of an experiment shall consist of reproducing the gondola motion as well as the instruments and graphics displays. No time distortion is being considered for this mode of replay.

2.4.2 Crewstation Drive Equipment Software

2.4.2.1 Simulation Control Computer Software

The Simulation Control Computer Software is primarily responsible for the digital control of the Dynamic Flight Simulator. This will include the realtime executive and mode control. The SCC software will also provide the inerface to the gondola/cockpit's visual displays, flight control systems and instrumentation display systems. The SCC provides the data conversions necessary for the interface between the digital simulation and the analog centrifuge control system.

The SCC software shall be developed by the contractor in a systematic top-down structured approach using the multitasking capabilities of the Sperry Univac VORTEX II operating system to their greatest advantage (Refer to Section 2.4.2.1.4). The software development tasks are broken down into the following functional subtasks: software design, programming/compiling, module test and debug, and software integration and test.

2.4.2.1.1 SCC Software Design Process

This process entails translating the SCC software requirements into detailed flowcharts suitable for programming. It consists of the following:

- A review of the functional requirements.
- The upper level functional design indicating required VORTEX II task configuration both resident and non-resident, including task definitions and priorities.
- The identification of the methods used for intertask communication. This may be a designation of an area in foreground common; it may be the intertask communication routines available on the system generation tape; or it may be any other intertask communication technique compatible with the VORTEX II environment.
- The identification of I/O requirements including interrupt handling and other special I/O requirements.

2.4.2.1.1.1 Special requirements for SCC Software Design

1) Application level modules shall be coded in FORTRAN unless approval is given to use assembly language (DASMR).

2) All application level I/O requests shall be processed using the VORTEX II I/O request processor. This is done in assembly language using the DASMR I/O macros or in FORTRAN using FORTRAN I/O statements.

3) Application level software shall use the multitasking capabilities of the VORTEX II operating system.

4) All I/O drivers on the SCC shall be interrupt driven.

5) The Common Interrupt Handler shall be used unless response time requires the use of directly connected interrupts. If directly connected interrupts are necessary then Option 2 (specifying 2 as the s(n) parameter on the PIM sysgen directive) shall be used unless approval is given to use Option 1.

6) All I/O driver errors shall be processed through he common error routine unless approval is given not to use it.

7) All I/O drivers, interrupt handlers, and controller tables shall be foreground resident, either in the VORTEX II nucleus or in the virtual nucleus overlay region of memory.

8) Every line of any assembly language subroutine must be commented.

9) A system generation library shall be created containing the complete system nucleus with all I/O drivers and interrupt handlers.

The functional subtasks of programming/compiling, module test and debug, and software integration and test shall be consistent with the CCS software development methodology described in Section 2.4.1 of this report.

2.4.2.1.2 SCC Software Tasks

The Simulation Control Computer (SCC) software shall include all computer programs necessary to:

1) Perform as the executive of the Dynamic Flight System and control the transfer of all data between the CDC 6600, the SCC and the gondola crewstation.

2) Synchronize the flow of data across the fiber optic interface.

3) Control the I/O signals for the Crewstation Cockpit instruments via the 1553B multiplex data bus.

4) Process the Centrifuge Control System I/O signals to control the simulated aircraft flight path.

5) Support the following graphic displays:

   a) Redifon Visual Display
   b) Head-Up Display
   c) VDI Symbol Generator
   d) HSD Symbol Generator
   e) Experiment Control Operator Display

6) Coordinate the experimental data collection.

The following sections describe in detail the SCC software tasks.

2.4.2.1.2.1 Executive Control Tasks

2.4.2.1.2.1.1 Start Up Task

Activation/Invocation:

The start up task is activated via a VORTEX II scheduling command from the system console. The command takes the form; SCHED START.

Inputs:

The inputs to the task are experiment control console inputs. The inputs will select system presets and operational modes.

Processing:

The start up task will establish communications with the CDC 6600. It shall also validate the operational readiness of the components which are necessary to perform the simulated mission.

Outputs:

The task will output status of all operational components and indicate when the initial communication with the CCS is completed.

2.4.2.1.2.1.2 System Monitor Task

Activation/Invocation:

Inputs:

The system monitor task will be initially activated by a scheduling action of the start up task. From then on it will reschedule itself.

Processing:

The system monitor task will set the SCC basic cycle time which controls all periodic tasks/functions in the SCC. The monitor task will also control all asynchronous I/O transfers.

Outputs:

The monitor task will start the task/function scheduling chain and all asynchronous I/O transfers. The asynchronous I/O transfers support the following equipment:

1. Redifon Visual Display Unit
2. Head-Up Display Unit
3. VDI Display Unit
4. HSD Display Unit
5. Experiment Control Operator Display

2.4.2.1.2.2 Fiber Optic I/O task

2.4.2.1.2.2.1 Fiber Optic Input Function

Activation/Invocation:

The fiber optic input task is scheduled via an interrupt from the fiber optic controller.

Inputs:

The data buffer from the fiber optic controller is the input to this function.

Processing:

The fiber optic input function will transfer the data block from the fiber optic controller in the fiber optic input buffer to the SCC. After the transfer is complete the task will enable the fiber optic output function.

Outputs:

The output from this function is the fiber optic input buffer.

2.4.2.1.2.2.2 Fiber Optic Output Function

Activation/Invocation:

This function is activated via a delay scheduling action of the System Monitor task.

Inputs:

The input to this function is the fiber optic output buffer.

Processing:

This task will transmit the fiber optic output buffer via the fiber optic controller to the CCS.

Outputs:

The fiber optic output task will transmit the data block.

2.4.2.1.2.3 Crewstation I/O Task (1553B Data Transfer)

2.4.2.1.2.3.1 Crewstation Input Function

Activation/Invocation:

The crewstation input function is activated via a delayed scheduling from the system monitor task. The delay time is set to the smallest delay possible

that still allows data to be collected prior to the completion of the basic cycle. By minimizing the delay, the data supplied to the DFS will show the smallest calculation lag.

Inputs:

The inputs to this task are all the crewstation variables necessary for the DFS aerodynamic control model. Data will be inputted to the SCC via the 1553B multiplex communications link.

Processing:

The function will read all required crewstation variables and place them into the fiber optic output buffer for transmission to CCS. This function will schedule the data collection task to write out the data collection blocks after the data is collected.

Outputs:

The outputs of this function are:

1. The DFS data block
2. The data collection task in a ready to run status

2.4.2.1.2.3.2 Crewstation Output Function

Activation/Invocation:

The crewstation output function is activated via a scheduling action of the fiber optic input task. This function shall run after the data is received by the fiber optic input function.

Inputs:

The input to this function is the DFS data block received by the fiber optic input funtion.

Processing:

This function will take the data block received by the fiber optic input function, validate it and output the crewstation variables to the crewstation via the 1553B multiplexed data bus.

2.4.2.1.2.4 Centrifuge Control Task

Activation/Invocation:

The gondola output function is activated via a scheduling action of the fiber optic input task. This function shall run immediately after the data is received by the fiber optic input function. In this way the least possible lag is introduced into the simulation.

Inputs:

The input to this function is the DFS data block received by the fiber optic input function.

Processing:

This function will validate the variables prior to transmitting the variables to the centrifuge.

Outputs:

The outputs are the centrifuge variables applied via the analog computer to the centrifuge.

2.4.2.1.2.5 Graphic Data Generation Tasks

2.4.2.1.2.5.1 Redifon Visual Display Function

Activation/Invocation:

The Redifon Visual Display task is a cyclic task which executes at some multiple of the basic cycle.

Inputs:

All data required by the Redifon display task is obtained from the fiber optic input buffer.

Processing:

The function will obtain the required variables from the buffer, modify the scaling if needed, and place the results into the Redifon output buffer.

Outputs:

The actual writing of the buffer to the Redifon display will be controlled by the system monitor task.

2.4.2.1.2.5.2 HUD Display Function

Activation/Invocation:

The HUD Display task is a cyclic task that executes at some multiple of the basic cycle.

Inputs:

All data required by the HUD display task is obtained from the fiber optic input buffer.

Processing:

The function will obtain the required variables from the buffers, modify the scaling if needed, and place the results into the HUD output buffer.

Outputs:

The actual writing of the buffer to the HUD display will be controlled by the system monitor task.

2.4.2.1.2.5.3 VDI and HSD Display Function

Activation/Invocation:

The VDI and HSD Display Tasks are cyclic tasks that execute at some multiple of the basic cycle.

Inputs:

All data required by the VDI and HSD display tasks are obtained from the fiber optic input buffer.

Processing:

The function will obtain the required variables from the buffer, modify the scaling if needed, and place the results into the VDI and HSD output buffers.

Outputs:

The actual writing of the buffers to the displays will be controlled by the system monitor task.

2.4.2.1.2.5.4 Experiment Control Operator Display Function

Activation/Invocation:

This function is activated periodically via a scheduling action of the system monitor task.

Inputs:

The inputs to the operator display function are the necessary variables in the fiber optic data blocks to format the required screen display.

Processing:

The operator display function will format a screen buffer from the data in the data blocks as determined by the experiment control operator in the operator input/mode control function.

Outputs:

The experiment control operator display function will completely format desired screen buffers so that the output function will be able to update the display in a timely manner.

2.4.2.1.2.5.5 Experiment Control Operator Input/Mode Control Function

Activation/Invocation:

This task is activated via an asynchronous interrupt from the experiment control operator console.

Inputs:

The inputs to this task are the operator key-ins which are used to determine the function desired by the operator. These key-ins may be used to change operational mode, system presets or data collections functions.

Processing:

After reading the operator key-in, the appropriate action is taken. This action may change the mode control word in the output data block, reformat the operator display data buffer or change the data collection control parameters.

Outputs:

The outputs of the operator input/mode control function are the required changes to the appropriate control words.

2.4.2.1.2.6 Experimental Data Collection Task

Activation/Invocation:

The experimental data collection task is activated periodically via a scheduling action of the monitor task.

Inputs:

The inputs to the data collection tasks are operator selections from available data.

Processing:

The data collection task will buffer the data blocks to mass storage.

Outputs:

The outputs from the data collection task are the data blocks blocked up in I/O buffers.

2.4.2.1.3 SCC Software Program Functional Flow

The SCC simulation software functions shall be executed by asynchronous tasks and periodic tasks. The partitioning of the tasks into asynchronous tasks and periodic tasks is given in Table XXX. Periodic tasks are begun at fixed portions of the basic cycle. Asynchronous tasks are executed in available time. All tasks must be completed within a basic cycle. Figure 50, illustrates the program flow as directed by the system monitor task.

2.4.2.1.3.1 Periodic Tasks

Periodic tasks in the SCC establish the system time for the entire simulation. The start of a basic cycle is delimited by the periodic monitor function. The Crewstation Input task (Section 2.4.2.1.2.3.1) is initiated shortly before the Fiber Optic Output function. In this way, the data transmitted to the CCS is not out-dated by more than a fixed, small, fraction of the basic cycle time. These tasks must be done once per cycle. Accordingly, they are of highest priority. The Experiment Control Operator Output task need not be done once per basic cycle. Accordingly, it need have only low priority.

2.4.2.1.3.2 Asynchronous Tasks

Asynchronous tasks in the SCC are those which are scheduled as a result of an external event. The external event may be an I/O interrupt, or a scheduling action in another task.

2.4.2.1.3.3 System Synchronization

System synchronization is maintained by the System Monitor task. Data cannot be transmitted at some time other than the start of a basic cycle. To do so would have the following implications:

TABLE XXX. SIMULATION CONTROL COMPUTER TASKS

MNEMONIC	TYPE	DESCRIPTION	PRIORITY	BUFFER SIZE	RESIDENCY
START	ONCE	start up			disk
FIBIN	ASYN	fiber optic input	interrupt high (1)	256	core
FIBOUT	PER	fiber optic output	high (1)	256	core
MTR	PER	monitor task	highest (0)		core
CREWIN	PER	crewstation input	higher (1)	10	core
CREWOUT	PER	crewstation output	high (2)	100	core
VDI	ASYN	display	high (2)	1000	core
HSD	ASYN	display	high (2)	1000	core
REDIF	ASYN	Redifon display	high (2)	1000	core
HUD	ASYN	Head-Up display	high (2)	2000	core
OPERIN	ASYN	operator input	interrupt higher (1)	100	core
OPEROUT	PER	operator output	low (3)	1000	core
DATCOL	ASYN	data collection	low (3)	1000	core

Legend:

ASYN means task not done at fixed time in basic cycle.
PER means task done at fixed time in basic cycle.
PRIORITIES are in reverse numerical order.
0 is the highest priority, 3 the lowest.

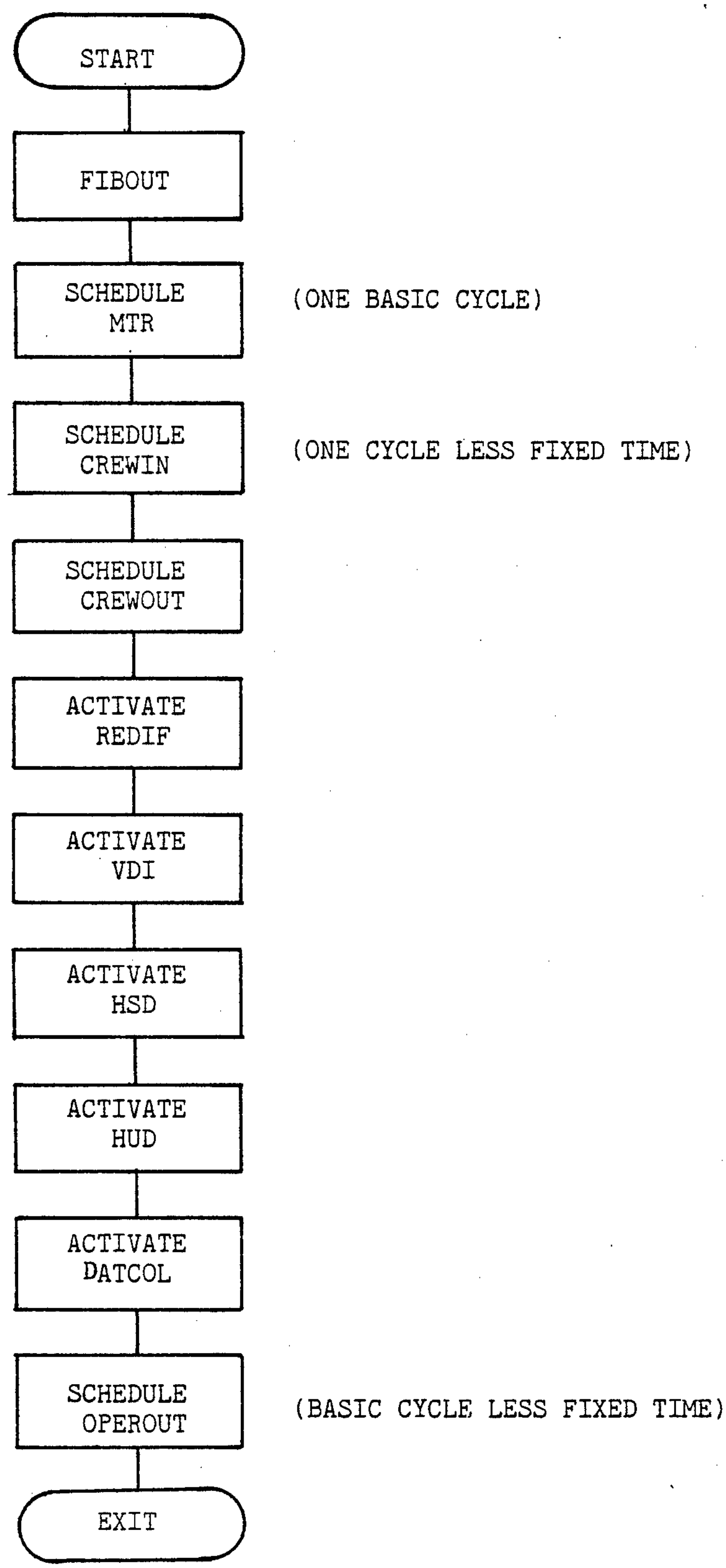


FIGURE 50. SCC PROGRAM FLOW

1. The DFS math models are predicated on a fixed cycle length. To introduce data at arbitrary times makes the determination of system time in terms of cycle length difficult.

2. A delay in data receipt from the CCS indicates a lack of processing time. Data transmission within the basic cycle would leave less time in the next cycle to complete CCS processing, thereby exacerbating the situation.

2.4.2.1.3.3.1 Normal Cycle

Data is transmitted to the DFS based upon the periodic fiber optic output task in the Simulation Control Computer. The crewstation input function for the next cycle is started via a delay scheduling action initiated by the periodic monitor task. The delay time is the longest possible, consistant with successful data gathering. Figure 51 indicates sequence of events for normal cycle.

2.4.2.1.3.3.2 Abnormal Cycle

An abnormal cycle is one which is not preceded by the Fiber Optic Input function. In this case, no data is transmitted by the Fiber Optic Output function but synchronization internal to the SCC is maintained. The Fiber Optic function resumes transmission only at the next normal cycle. Figure 52 indicates sequence of events for an abnormal cycle.

2.4.2.1.4 SCC Operating System

The Simulation Control Computer (Sperry Univac V77-600) uses the VORTEX II operating system. VORTEX II is a modular software operating system for controlling, scheduling, and monitoring tasks in a real-time multiprogramming environment. It supports memory map operation to a maximum of 1024K of central memory and also provides for background operations such as compilation, assembly, debugging, or execution of tasks not associated with the real-time functions of the system. The basic features of VORTEX II are:

- Memory map management
- Real-time I/O processing
- Provision for directly connected interrupts
- Interrupt processing
- Multiprogramming of real-time and background tasks
- Overlapping output to peripherals with spooling
- Priority task scheduling (clock time or interrupt)
- Load and go (automatic)
- Centralized and device-independent I/O system using logical unit and file names
- Operator communications
- Batch-processing job-control language
- Program overlays

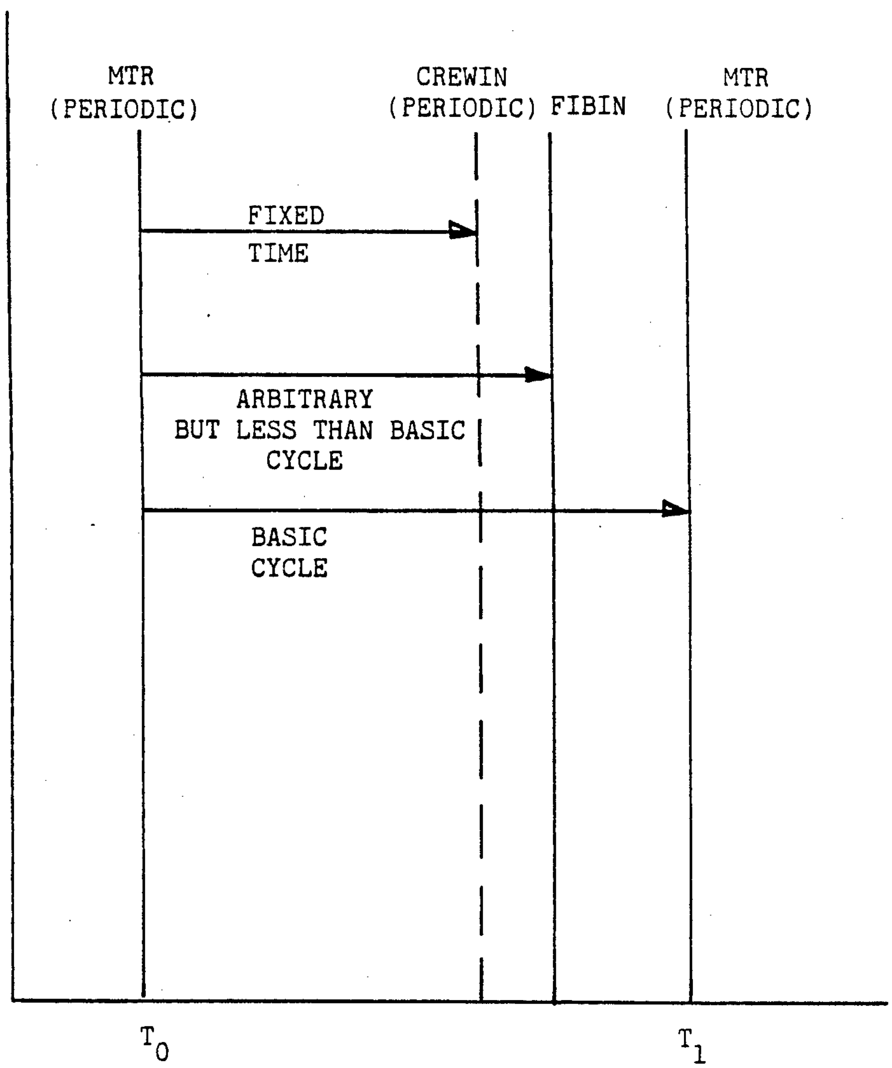


FIGURE 51. NORMAL CYCLE SEQUENCE OF EVENTS (DATA RECEIVED LATE DURING BASIC CYCLE)

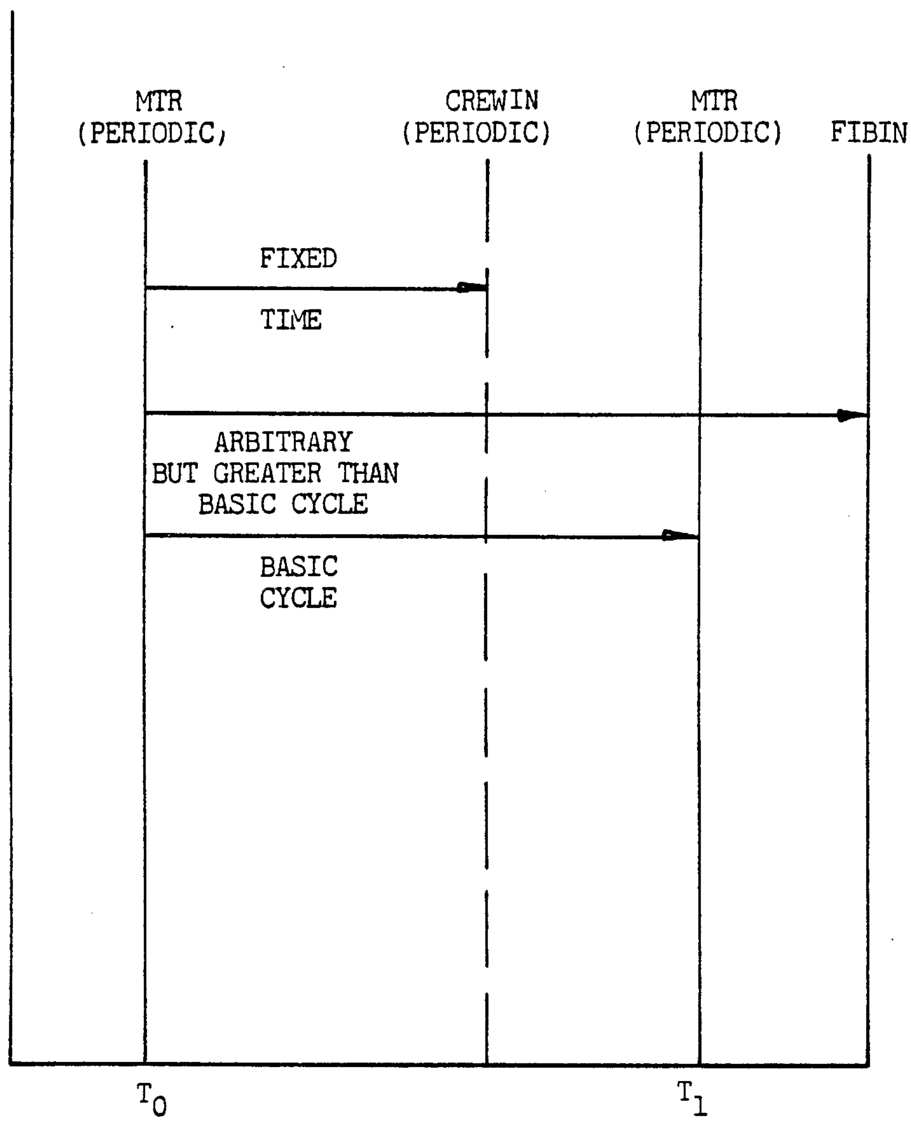


FIGURE 52. ABNORMAL CYCLE SEQUENCE OF EVENTS (DATA RECEIVED LATE AFTER BASIC CYCLE)

- o Background programming aids: FORTRAN and DAS MR assembler, load-module generator, library updating, debugging, and source editor.
- o Use of background area when required by foreground tasks
- o Disc/drum directories and references
- o System generator
- o Individual task protection

Figure 53 is an overview of the flow in the VORTEX operating system.

VORTEX requires the following minimum hardware configuration:

a. SPERRY UNIVAC 70 series computers with 64K memory.

b. 33/35 ASR Teletype or compatible CRT on a priority interrupt module.

c. Priority Interrupt Module (PIM)

d. Rotating memory device (RMD) on a PIM with either a block transfer controller (BTC) or direct memory interface, 80 M bytes unformatted

e. One of the following on a PIM:

(1) Paper tape system or a paper tape reader
(2) Magnetic tape unit with a BIC

f. Memory map hardware

The system supports and is enhanced by the following optional hardware items:

a. Additional main memory (up to a total of 1024K)

b. Automatic bootstrap loader with VORTEX II (device dependent) system boot

c. Paper-tape punch, if one is not included in the minimum system

d. Process input and output A/D, D/A

e. V75 extended instruction set.

All BICs, BTCs and DCMs must have memory mapping capability.

The rotating memory device (RMD) serves as storage for the VORTEX operating system components, enabling real-time operations and a multiprogramming environment for solving real-time and nonreal-time problems. Real-time processing is implemented by hardware interrupt controls and software tasks scheduling. Tasks are scheduled for execution by operator requests, other tasks, device interrupts, or the completion of time intervals.

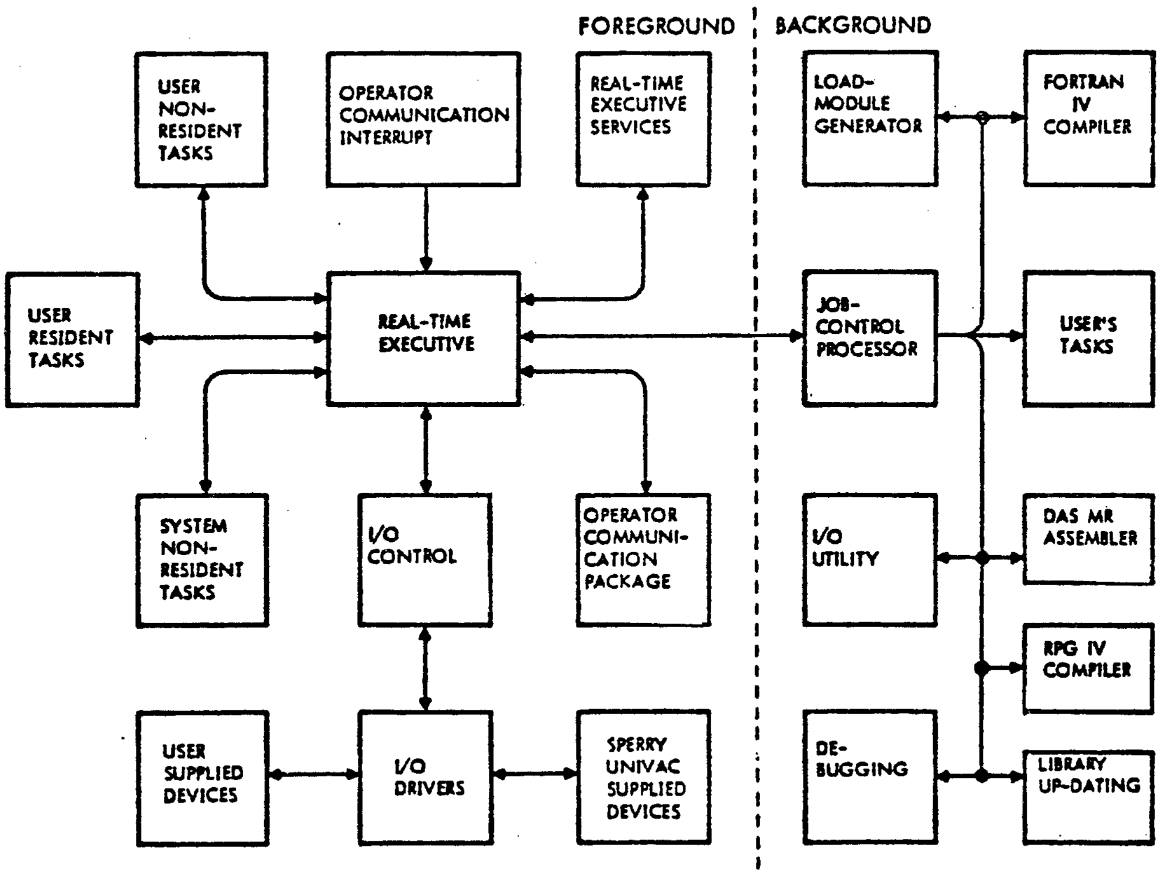


FIGURE 53. VORTEX OPERATING SYSTEM

Background processing (nonreal-time) operations, such as FORTRAN compilations or DASMR assemblies, are under control of the job-control processor itself a VORTEX background task. These background processing operations are performed simultaneously with the real-time foreground tasks until execution of the former is suspended, either by an interrupt or a scheduled task.

VORTEX executes foreground and background tasks scheduled by operator requests, interrupts, or other tasks. All tasks are scheduled, activated, and executed by the real-time executive component on a priority basis. Thus, in the VORTEX operating system, each task has a level of priority that determines what will be executed first when two or more tasks come up for execution simultaneously.

The job-control processor component of the VORTEX system manages requests for the scheduling of background tasks.

Upon completion of a task, control returns to the real-time executive. In the case of a background task, the real-time executive schedules the job-control processor to determine if there are any further background tasks for execution. During execution, any foreground task can use any real-time executive service.

VORTEX requires a minimum of 32K words of main memory and supports up to a maximum of 1024K words. The system generation programs execute in a non-memory map environment and consequently utilize only the first physical 32K words of main memory.

2.4.2.2 Visual Display System Software

This section details the software equations required to define the position and attitude relationships for the Redifon SP-2 visual display system.

The equations presented will be computed in the Simulation Control Computer for subsequent transfer to the visual display processor via the digital interface.

Pitch, roll and heading attitudes, latitude, longitude and height positions of the selected aircraft model shall be variables generated by the CCS CDC 6600 as described in Section 2.4.1.

2.4.2.2.1 System Requirements

The DFS visual display system is designed to generate various real-world scenes. These scenes may be either an airfield, an aircraft carrier, or a target aircraft. (See Section 2.3.2.1 for detailed system capabilities). Visual drive equations are required to give relative positions between the pilot's eye and the selected model origin. Figure 54 (a) shows the coordinate relationship for the visual heading and the airfield, where axes X and Y coincide with the simulator North and East vectors. Figure 54 (b) shows pilot eye position relative to aircraft cg. Figure 55 contains a review of visual geometry conventions.

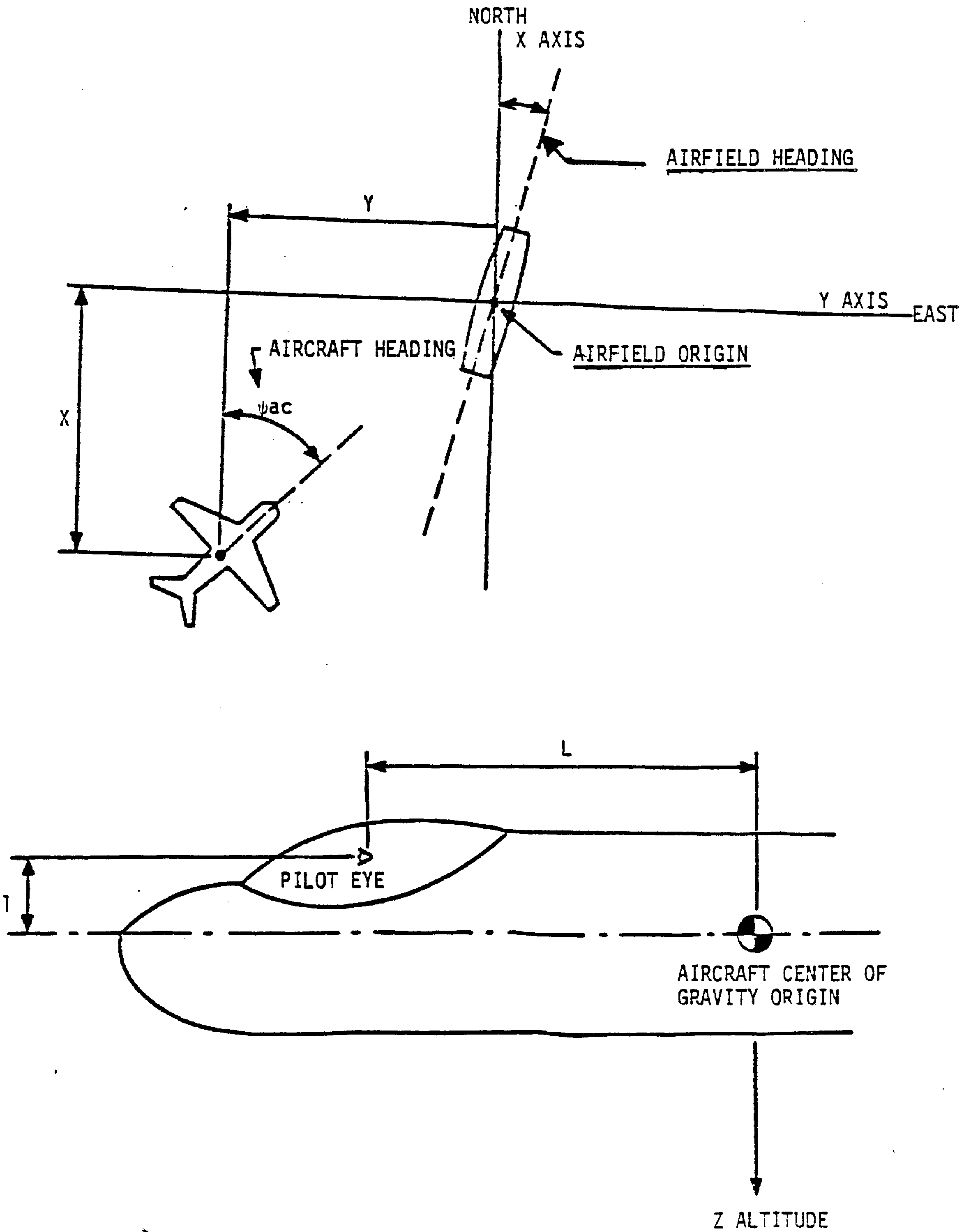


FIGURE 54. PILOT EYE POSITION RELATIVE TO AIRCRAFT ORIGIN

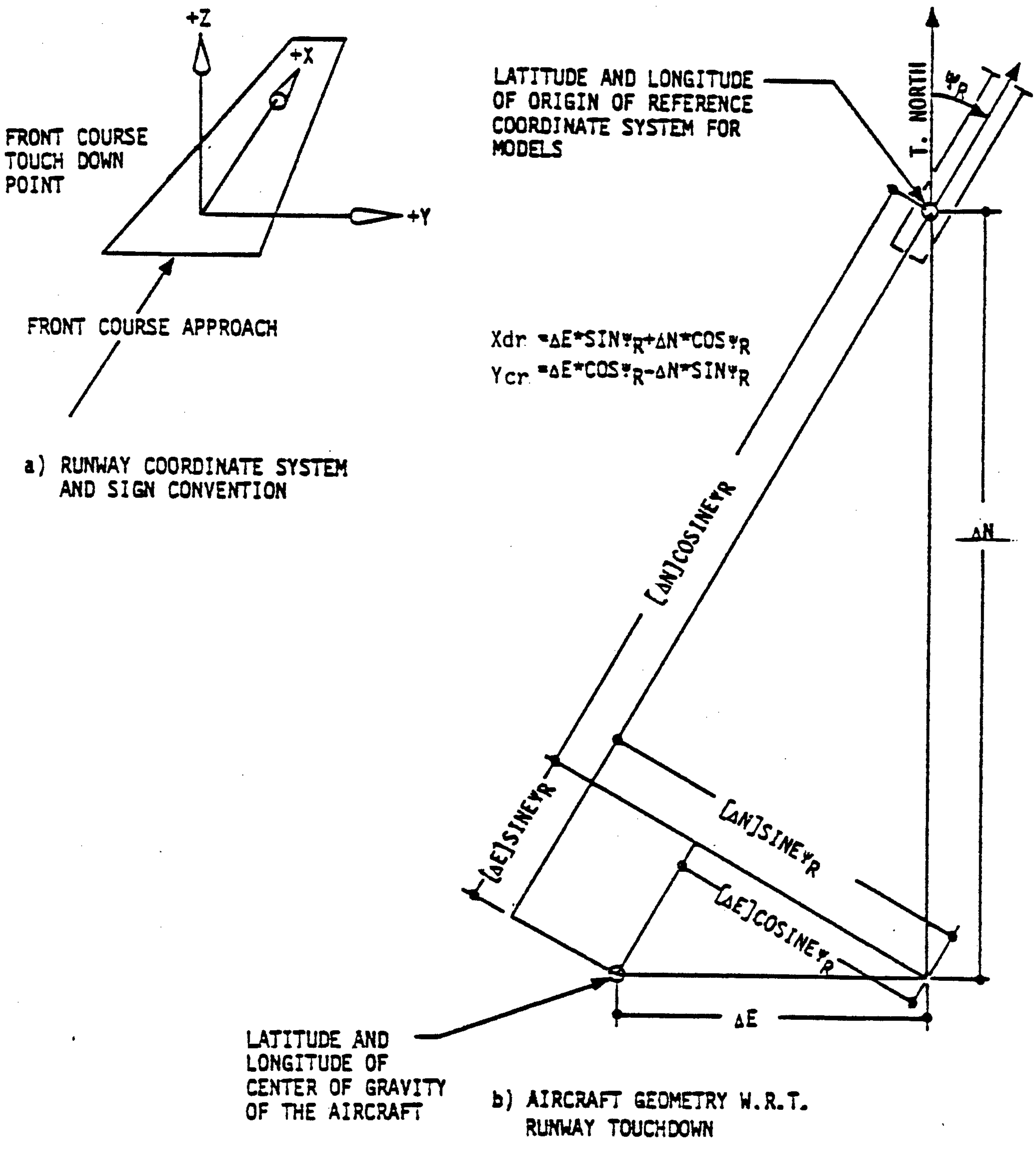


FIGURE 55. VISUAL GEOMETRY CONVENTIONS

2.4.2.2.2 Software Requirements

NAVAIRDEVCEN shall code and assemble the visual programs resident in the simulation control computer (otherwise called the host computer) consistent with the 32-word host input block described in Section 2.4.2.2.5.

In general, the visual system shall receive the following data from the simulation control computer:

1) Aircraft cg position in X, Y, and Z coordinates above data base.

2) Aircraft pitch, roll, and heading.

3) Visual environment and light controls as described in Section 2.4.2.2.3.

4) Miscellaneous settings for control bits.

2.4.2.2.3 Switch Number Sequence

A software subroutine will be written which will set up four (4) blocks of memory, eight (8) words in each. These blocks and words will represent the switch number sequence detailed in Table XXXI.

Bits 8-10 of each of the 32 words will contain brightness level; bits 11-15, as assembled data, will contain the corresponding switch number (0-31). The result is shown in Table XXXII.

2.4.2.2.4 Switch Setting/Switch Number Block

When the Runway Select Activate Momentary Switch is pressed, the brightness levels of the switches are read into bits 8, 9 and 10 of the particular Runway Block. In addition, the particular runway block is copied into an 8 word buffer for transfer to the visual display processor. In this way, correct brightness/switch number correlation is obtained.

The 8 word buffer will look as shown in Table XXXIII.

Each frame successive BRIGHTNESS/SWITCH NO. value is transferred to the visual display processor. After the number 7 value is transferred, return is to the number 0 value and the sequence is repeated.

TABLE XXXI. Switch Setting/Switch Number Sequence

	RWY 0	RWY 1	RWY 2	OTHER OR RWY 3
APPROACH	0	8	16	24
RWY. EDGE	1	9	17	25
CENTER LINE	2	10	18	26
TAXI	3	11	19	27
VASI	4	12	20	28
TDZ	5	13	21	29
STROBE	6	14	22	30
REILS	7	15	23	31

TABLE XXXII. SWITCH SETTING/SWITCH NUMBER BLOCK

BIT POSITION 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

WORD			Brightness	11	12	13	14	15	
Approach	0		Brightness 000 thru 101					0	Runway No. ∅
Runway Edge	1							1	
Center Line	2						1	0	
Taxi	3						1	1	
VASI	4					1	0	0	
TDZ	5					1	0	1	
Strobe	6					1	1	0	
REILS	7					1	1	1	
Approach	8				1	0	0	0	Runway 1, 2, 3
Runway Edge	9				1	0	0	1	
Center Line	10				1	0	1	0	
Taxi	11				1	0	1	1	
VASI	12				1	1	0	0	
⋮									
REILS	31			1	1	1	1	1	

TABLE XXXIII

SWITCH SETTING/SWITCH NUMBER BUFFER

WORD	BIT POSITION	0 1 2 3 4 5 6 7	8 9	10 11 12 13 14 15
Approach	0		Brightness Values	Switch Numbers Corresponding to Runway Selected
Runway Edge	1			
Center Line	2			
Taxi	3			
VASI	4			
TDZ	5			
Strobe	6			
REILS	7			

2.4.2.2.5 Host Input Block

Input from the host computer will be transferred in blocks of 32 words as shown in Figure 56 and described below:

VISOUT = Word 1 Bit 0	Display ON/OFF. Both software and hardware cycles disables when OFF. (System Control ON/OFF)
Bits 1-6	Set to zero.
Bit 7	Active indicator for model group selection. (INSERT switch) Indicates when group number is correct and should be sampled. Need only be set for 1 frame.
Bit 8	Set to zero.
Bits 9-15	Binary code for one of 128 possible groups (Data Base) to be activated. (DATA BASE SELECT)
VISOUT + 1 = Word 2	Visibility in feet, scaled B18. When the visibility digits on the control panel are all zero, load this word with RVR in feet, scaled B18. (VISIBILITY)
VISOUT + 2 = Word 3	Ground fog RVR in feet, scaled B18. Used for visibility in ground fog. Put RVR value in here at all times.
VISOUT + 3 = Word 4	Altitude of top of cloud layer in feet above field evaluation, scaled B17. (CLOUDTOP)
Word 5	Altitude of top of cloud layer in feet above field evaluation, scaled B17. (CEILING)
Word 6 Bits 0-7	Heading of brightest point of directional horizon relative to model origin heading.
Bits 8-10	Switch setting (brightness level) of lights assigned to switch number given in bits 11-15 legal codes are 0 through 5 only (APR, RWY, STROBE, REIL, VASI).
Bits 11-15	Binary code for one of 32 switch groups. See Table XXX for switch number sequence. A valid number must be sent each frame.
Word 7 Bits 0-2	Switch setting (brightness level) of horizon. Only codes 0 through 5 are legal. (HOR BRIGHT)
Bit 3	ON/OFF control of directional horizon. (1=ON)

ITEM NUMBER	MNEMONIC PROGRAM		UPDATE RATE	UNITS	BINARY SCALING	BIT TRANSFER POSITIONS / TI 980 BIT TRANSFER POSITIONS: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 — WORD DESCRIPTION
1	VISØUT		1/4	BITS	~	(0) ON OFF; (7) MODEL CHANGE; (8) DO NOT USE; (9–15) MODEL NUMBER (BINARY)
2	+1		1/4	FT	B18	⊕ 2^{17} VISIBILITY OR (RVR when visibility digits are zero) 2^{3}
3	+2		1/4	FT	B18	⊕ 2^{17} GROUND FOG RVR 2^{3}
4	+3		1/4	FT	B17	⊕ 2^{16} CLOUDTOP w.r.t. SEA LEVEL 2^{2}
5	+4		1/4	FT	B17	⊕ 2^{16} CEILING w.r.t. GROUND ELEVATION 2^{2}
6	+5		1/4	DEG 180	B0	180° 90° 45° DIRECTIONAL HORIZON HEADING; L.P. BRIGHTNESS SWITCH SETTING; STRING TYPE BRIGHTNESS SWITCH NUMBER
7	+6		1/4	BITS	~	HORIZON BRIGHTNESS; BIG HORIZON; BEACON; SCUD; GROUND FOG; AMB. ART; LANDING LIGHT LEFT; CENTER; LOBES RIGHT
8	+7		~	BITS		SPARE
9	+8		1/4			SPARE
10	+9		~			SPARE
11	+10		MAX	DEG 180	B0	180° 90° 45° AIRCRAFT TRUE HEADING RELATIVE TO ACTIVE RUNWAY TRUE HEADING ANGLE ⊕ YAW RIGHT
12	+11		MAX	DEG 180	B0	180° 90° 45° AIRCARFT BODY PITCH ANGLE ⊕ PITCH UP
13	+12		MAX	DEG 180	B0	180° 90° 45° AIRCRAFT BODY ROLL ANGLE ⊕ ROLL RIGHT
14	+13		MAX	FEET	B22	SIGN 2^{21} DOUBLE WORD PILOTS EYE DOWNRANGE w.r.t. RUNWAY, MOST SIG 2^{7}
15	+14		MAX	FEET	B7	SIGN 2^{6} ⊕ FWD OF T.D. POINT 2^{0} , LEAST SIG 2^{-8}
16	+15		MAX	FEET	B22	SIGN 2^{21} DOUBLE WD PILOTS EYE CROSSRANGE w.r.t. RUNWAY, MOST SIG 2^{7}
17	+16		MAX	FEET	B7	SIGN 2^{6} ⊕ RT OF MAIN ℄ 2^{0} , LEAST SIG 2^{-8}
18	+17		MAX	FEET	B22	SIGN 2^{21} DOUBLE WD PILOTS EYE ALTITUDE w.r.t. RUNWAY , MOST SIG 2^{7}
19	+18		MAX	FEET	B7	SIGN 2^{6} ⊕ ABV RNY 2^{0} , LEAST SIG 2^{-8}
20	+19		MAX	DEG 180	B0	180° 90° 45° 1st DYNAMIC MODULE RELATIVE HEADING
21	+20		MAX	DEG 180	B0	180° 90° 45° 1st DYNAMIC MODULE PITCH ANGLE
22	+21		MAX	DEG 180	B0	180° 90° 45° 1st DYNAMIC MODULE ROLL ANGLE
23	+22		MAX	FEET	B22	SIGN 2^{21} 1st DYNAMIC MODULE DOUBLE WORD DOWNRANGE, MOST SIG. 2^{7}
24	+23		MAX	FEET	B7	SIGN 2^{6} 2^{0} , LEAST SIG 2^{-8}
25	+24		MAX	FEET	B22	SIGN 2^{21} 1st DYNAMIC MODULE DOUBLE WORD CROSSRANGE, MOST SIG 2^{7}
26	+25		MAX	FEET	B7	SIGN 2^{6} 2^{0} , LEAST SIG 2^{-8}
27	+26		MAX	FEET	B22	SIGN 2^{21} 1st DYNAMIC MODULE DOUBLE WORD ALTITUDE, MOST SIG 2^{7}
28	+27		MAX	FEET	B7	SIGN 2^{6} 2^{0} , LEAST SIG 2^{-8}
29	+28		MAX	DEG 180	B0	180° 90° 45° 2nd DYNAMIC MODULE RELATIVE HEADING
30	+29		MAX	DEG 180	B0	180° 90° 45° 2nd DYNAMIC MODULE PITCH ANGLE
31	+30		MAX	DEG 180	B0	180° 90° 45° 2nd DYNAMIC MODULE ROLL ANGLE
32	+31		MAX		~	CHECKSUM, EXCLUSIVE - OR OF FIRST 31 WORDS

FIGURE 56. VISUAL DISPLAY HOST COMPUTER BIT TRANSFER

	Bit 4	Set to zero.
	Bit 5	ON/OFF control of aircraft bi-intensity strobe an its effect on glare in clouds. (From simulator overhead panel)
	Bit 6	Set to zero.
	Bit 7	ON/OFF control of scud cloud effects. (SCUD)
	Bit 8	ON/OFF control of ground fog layer. (GROUND FOG)
	Bit 9	Set to zero.
	Bits 10-11	Switch setting (brightness level) of NIGHT/DUSK/DAY ground and top of cloud illuminations. Only codes 0 through 2 are legal. (AMB)
	Bit 12	Set to zero.
	Bits 13-15	Left, center, or right landing lights ON/OFF (from simulator overhead panel).
Word 8		Unused on this installation. Set to zero.
Word 9		Unused on this installation. Set to zero.
Word 10		Unused on this installation. Set to zero.
Words 11-13		Heading, pitch, and roll of aircraft in fractions of half circle (DEG/180, scale-B0).
Words 14-19		Double precision pilot's eye X, Y, and Z coordinates relative to model origin in feet scaled B22.
Words 20-28		Euler angles and position of vector of object on first dynamic coordinate system.
Words 29-31		Euler angles for chained second dynamic coordinate system.
Word 32		Exclusive - OR checksum of previous 31 words.

2.4.2.2.6 Visual Display Processor Data Format

The Visual Display Processor utilizes Texas Instrument 980 double precision format for all data. This format is shown below:

```
          MOST SIGNIFICANT                      LEAST SIGNIFICANT
 ____________________________________________________________________
!S        !          !          !          !S        !          !          !
 --------------------------------------------------------------------
 S = Sign Bit
```

If the host computer data format is different, the X, Y, and Z double precision words must be converted to this format after calculation and before storage in the host input data block.

2.4.2.3 Head Up Display and Cockpit Display Symbol Generator Software

The Dynamic Flight Simulator software shall supply modules which format blocks or data in a manner consistent with the input block requirements of the Head Up Display and Cockpit Display Symbol generators. The Dynamic Flight Simulator software shall conform to the software interface requirements of the respective symbol generators. (Refer to Section 2.3.2.3 for equipment description).

2.4.2.4 Analog Computer System Software

The analog computer will be programmed to properly handle the analog data which must be sent to and from the analog centrifuge control system. Programming is required to handle the analog data itself as well as the control of the analog data interface.

Data sent to the centrifuge control system is limited and conditioned to provide proper signals to the centrifuge motion. Data sent from the centrifuge control system is conditioned to provide the proper source impedance and bandwidth and to provide the required isolation between the control system and the external system.

The analog data interface control functions to be performed include: external system activity detection, motion control transfer logic and stop request logic for stopping the centrifuge.

2.4.3 Centrifuge Gondola Crewstation Software

2.4.3.1 Secs 80 Microprocessor Software

2.4.3.1.1 System Requirements

The Secs 80 Microprocessor will act as an I/O Controller for all signals sent to and from the Gondola Crewstation. The system will receive data from the SCC along a 1553B multiplex data bus and will forward it to the appropriate D/A converters for display on the instruments in the crewstation cockpit. Signals originating from the crewstation controls will be converted to digital signals by the microprocessor A/D converters and then transmitted to the SCC via the 1553B bus.

2.4.3.1.2 Microprocessor Software Design

The Secs 80 software will be written in Intel 8080 assembly language and developed on an Intel Development system. The Secs 80 was selected because of the general familiarity of the Intel 8080 instruction set. The complete instruction set is shown in Figure 57.

JUMP

C3	JMP	
C2	JNZ	
CA	JZ	
D2	JNC	
DA	JC	
E2	JPO	
EA	JPE	
F2	JP	
FA	JM	Adr
E9	PCHL	

CALL

CD	CALL	
C4	CNZ	
CC	CZ	
D4	CNC	
DC	CC	
E4	CPO	
EC	CPE	
F4	CP	
FC	CM	Adr

RETURN

C9	RET
C0	RNZ
C8	RZ
D0	RNC
D8	RC
E0	RPO
E8	RPE
F0	RP
F8	RM

RESTART

C7	RST	0
CF	RST	1
D7	RST	2
DF	RST	3
E7	RST	4
EF	RST	5
F7	RST	6
FF	RST	7

ROTATE†

07	RLC
0F	RRC
17	RAL
1F	RAR

CONTROL

00	NOP
76	HLT
F3	DI
FB	EI

MOVE IMMEDIATE

06	MVI	B,	
0E	MVI	C,	
16	MVI	D,	
1E	MVI	E,	
26	MVI	H,	
2E	MVI	L,	
36	MVI	M,	
3E	MVI	A,	D8

Acc IMMEDIATE*

C6	ADI	
CE	ACI	
D6	SUI	
DE	SBI	
E6	ANI	
EE	XRI	
F6	ORI	
FE	CPI	D8

LOAD IMMEDIATE

01	LXI	B,	
11	LXI	D,	
21	LXI	H,	
31	LXI	SP,	D16

DOUBLE ADD†

09	DAD	B
19	DAD	D
29	DAD	H
39	DAD	SP

STACK OPS

C5	PUSH	B
D5	PUSH	D
E5	PUSH	H
F5	PUSH	PSW
C1	POP	B
D1	POP	D
E1	POP	H
F1	POP	PSW*
E3	XTHL	
F9	SPHL	

MOVE

40	MOV	B,B
41	MOV	B,C
42	MOV	B,D
43	MOV	B,E
44	MOV	B,H
45	MOV	B,L
46	MOV	B,M
47	MOV	B,A
48	MOV	C,B
49	MOV	C,C
4A	MOV	C,D
4B	MOV	C,E
4C	MOV	C,H
4D	MOV	C,L
4E	MOV	C,M
4F	MOV	C,A
50	MOV	D,B
51	MOV	D,C
52	MOV	D,D
53	MOV	D,E
54	MOV	D,H
55	MOV	D,L
56	MOV	D,M
57	MOV	D,A

MOVE (cont)

58	MOV	E,B
59	MOV	E,C
5A	MOV	E,D
5B	MOV	E,E
5C	MOV	E,H
5D	MOV	E,L
5E	MOV	E,M
5F	MOV	E,A
60	MOV	H,B
61	MOV	H,C
62	MOV	H,D
63	MOV	H,E
64	MOV	H,H
65	MOV	H,L
66	MOV	H,M
67	MOV	H,A
68	MOV	L,B
69	MOV	L,C
6A	MOV	L,D
6B	MOV	L,E
6C	MOV	L,H
6D	MOV	L,L
6E	MOV	L,M
6F	MOV	L,A
70	MOV	M,B
71	MOV	M,C
72	MOV	M,D
73	MOV	M,E
74	MOV	M,H
75	MOV	M,L

77	MOV	M,A
78	MOV	A,B
79	MOV	A,C
7A	MOV	A,D
7B	MOV	A,E
7C	MOV	A,H
7D	MOV	A,L
7E	MOV	A,M
7F	MOV	A,A

INCREMENT**

04	INR	B
0C	INR	C
14	INR	D
1C	INR	E
24	INR	H
2C	INR	L
34	INR	M
3C	INR	A
03	INX	B
13	INX	D
23	INX	H
33	INX	SP

DECREMENT**

05	DCR	B
0D	DCR	C
15	DCR	D
1D	DCR	E
25	DCR	H
2D	DCR	L
35	DCR	M
3D	DCR	A
0B	DCX	B
1B	DCX	D
2B	DCX	H
3B	DCX	SP

LOAD/STORE

0A	LDAX	B
1A	LDAX	D
2A	LHLD	Adr
3A	LDA	Adr
02	STAX	B
12	STAX	D
22	SHLD	Adr
32	STA	Adr

SPECIALS

EB	XCHG
27	DAA*
2F	CMA
37	STC†
3F	CMC†

INPUT/OUTPUT

D3	OUT	
DB	IN	D8

ACCUMULATOR*

80	ADD	B
81	ADD	C
82	ADD	D
83	ADD	E
84	ADD	H
85	ADD	L
86	ADD	M
87	ADD	A
88	ADC	B
89	ADC	C
8A	ADC	D
8B	ADC	E
8C	ADC	H
8D	ADC	L
8E	ADC	M
8F	ADC	A
90	SUB	B
91	SUB	C
92	SUB	D
93	SUB	E
94	SUB	H
95	SUB	L
96	SUB	M
97	SUB	A
98	SBB	B
99	SBB	C
9A	SBB	D
9B	SBB	E
9C	SBB	H
9D	SBB	L
9E	SBB	M
9F	SBB	A
A0	ANA	B
A1	ANA	C
A2	ANA	D
A3	ANA	E
A4	ANA	H
A5	ANA	L
A6	ANA	M
A7	ANA	A
A8	XRA	B
A9	XRA	C
AA	XRA	D
AB	XRA	E
AC	XRA	H
AD	XRA	L
AE	XRA	M
AF	XRA	A
B0	ORA	B
B1	ORA	C
B2	ORA	D
B3	ORA	E
B4	ORA	H
B5	ORA	L
B6	ORA	M
B7	ORA	A
B8	CMP	B
B9	CMP	C
BA	CMP	D
BB	CMP	E
BC	CMP	H
BD	CMP	L
BE	CMP	M
BF	CMP	A

PSEUDO INSTRUCTION

ORG	Adr
END	
EQU	D16
SET	D16
DS	D16
DB	D8 [ ]
DW	D16 [ ]
IF	D16
ENDIF	
MACRO	[ ]
ENDM	

CONSTANT DEFINITION

0BDH, 1AH	Hex
105D, 105	Decimal
72O, 72Q	Octal
11011B, 00110B	Binary
'TEST', 'A' 'B'	ASCII

OPERATORS

( )
*, /, MOD, SHL, SHR
+, -
NOT
AND
OR, XOR

STANDARD SETS

A	SET	7
B	SET	0
C	SET	1
D	SET	2
E	SET	3
H	SET	4
L	SET	5
M	SET	6
SP	SET	6
PSW	SET	6

D8 = constant, or logical/arithmetic expression that evaluates to an 8 bit data quantity.

* = all Flags (C, Z, S, P, AC) affected

D16 = constant, or logical/arithmetic expression that evaluates to a 16 bit data quantity.

† = only CARRY affected

Adr = 16 bit address

** = all Flags except CARRY affected; (exception: INX & DCX affect no Flags)

FIGURE 57. INTEL 8080 INSTRUCTION SET

The Secs 80 Microprocessor software program will be developed in a top-down structured approach with each line of code clearly commented. Subprograms will be written and tested on an individual basis before being incorporated into the master program.

2.4.3.1.3 Microprocessor Software Tasks

Assembly language routines will be developed to perform the following tasks:

(1) I/O Drivers for A/D interfaces
(2) I/O Drivers for D/A interfaces
(3) I/O Drivers for Discrete Signals
(4) 1553B Data Conversion Routine
(5) Executive Control Routine
(6) Interrupt Handler Routine

Detailed program design will be developed as required.

3.0 Dynamic Flight Simulator System Development Work Breakdown Structure

3.1 System Work Breakdown Structure

The system development work breakdown structure, illustrated in Figure 58, includes system analysis, software, hardware, integration, and operational task preparation.

3.2 Detailed Work Breakdown Structures

Detailed work breakdown structures for the simulation software and hardware development are presented in Figures 59 and 60. Detailed work breakdown structures for the laboratory and centrifuge integration, the F-14 aircraft spin operational task preparation and various analysis studies will be developed as the Dynamic Flight Simulator Program progresses.

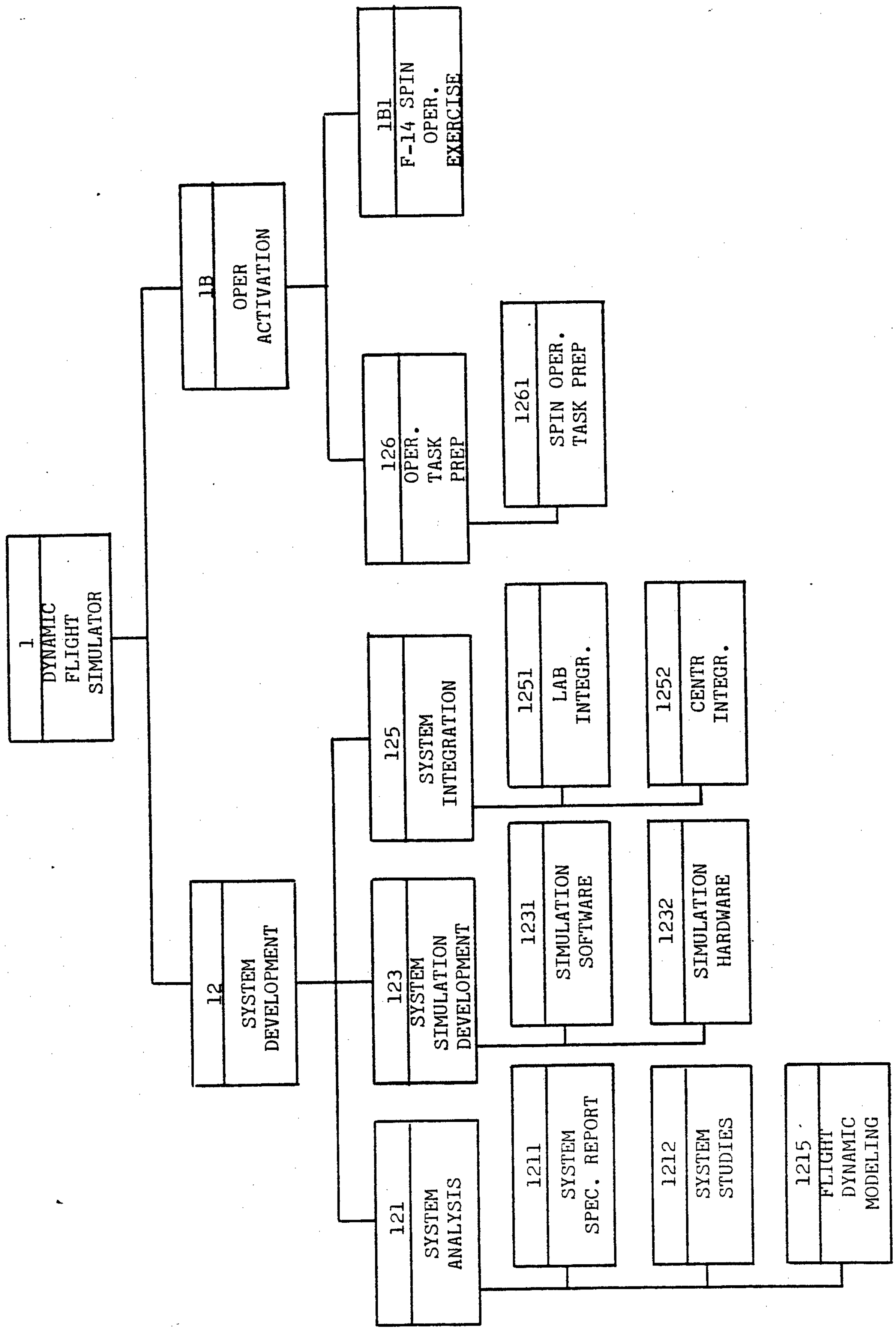


FIGURE 58. DYNAMIC FLIGHT SIMULATOR WORK BREAKDOWN STRUCTURE

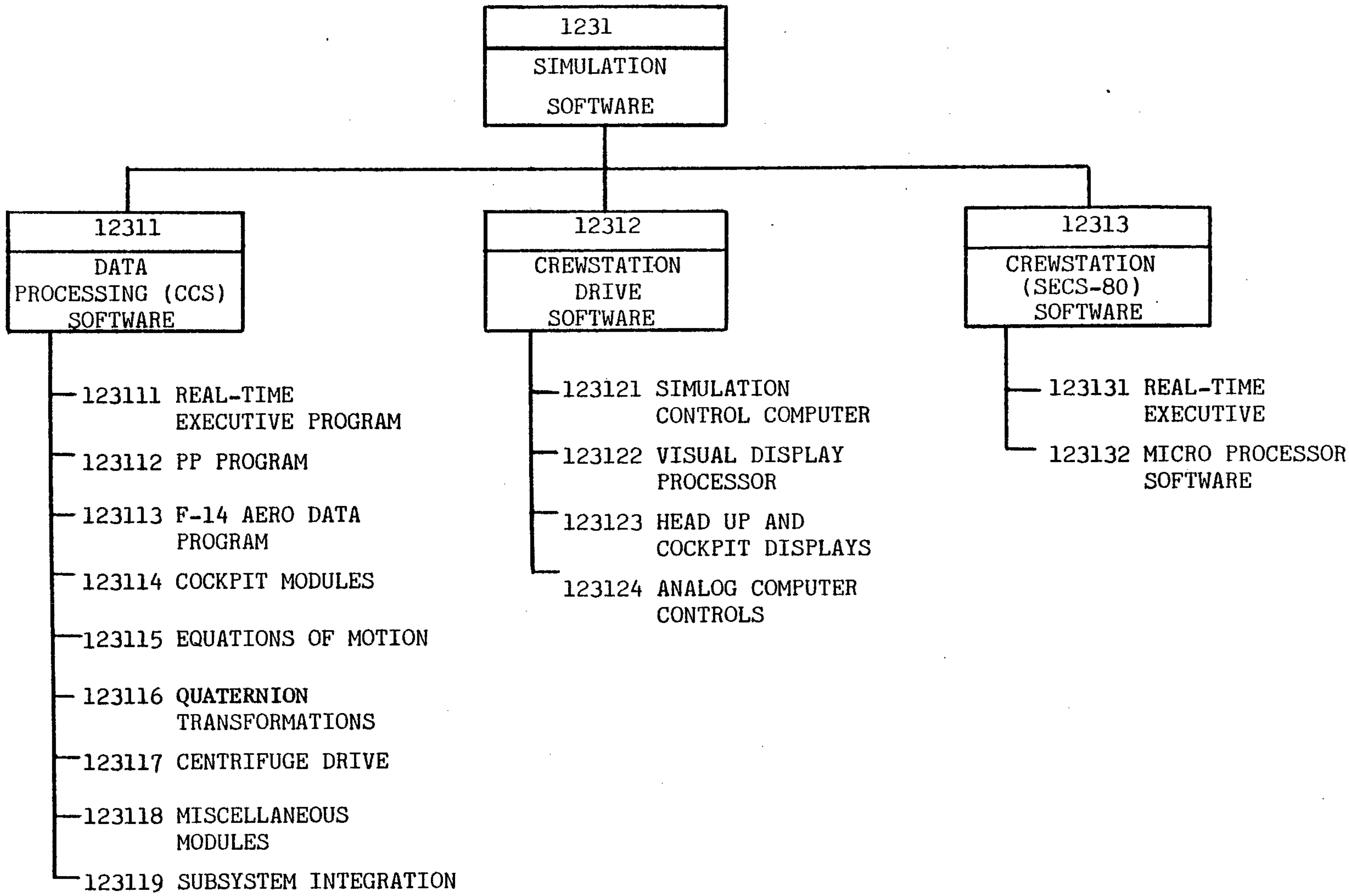


FIGURE 59. DYNAMIC FLIGHT SIMULATOR SOFTWARE WORK BREAKDOWN STRUCTURE

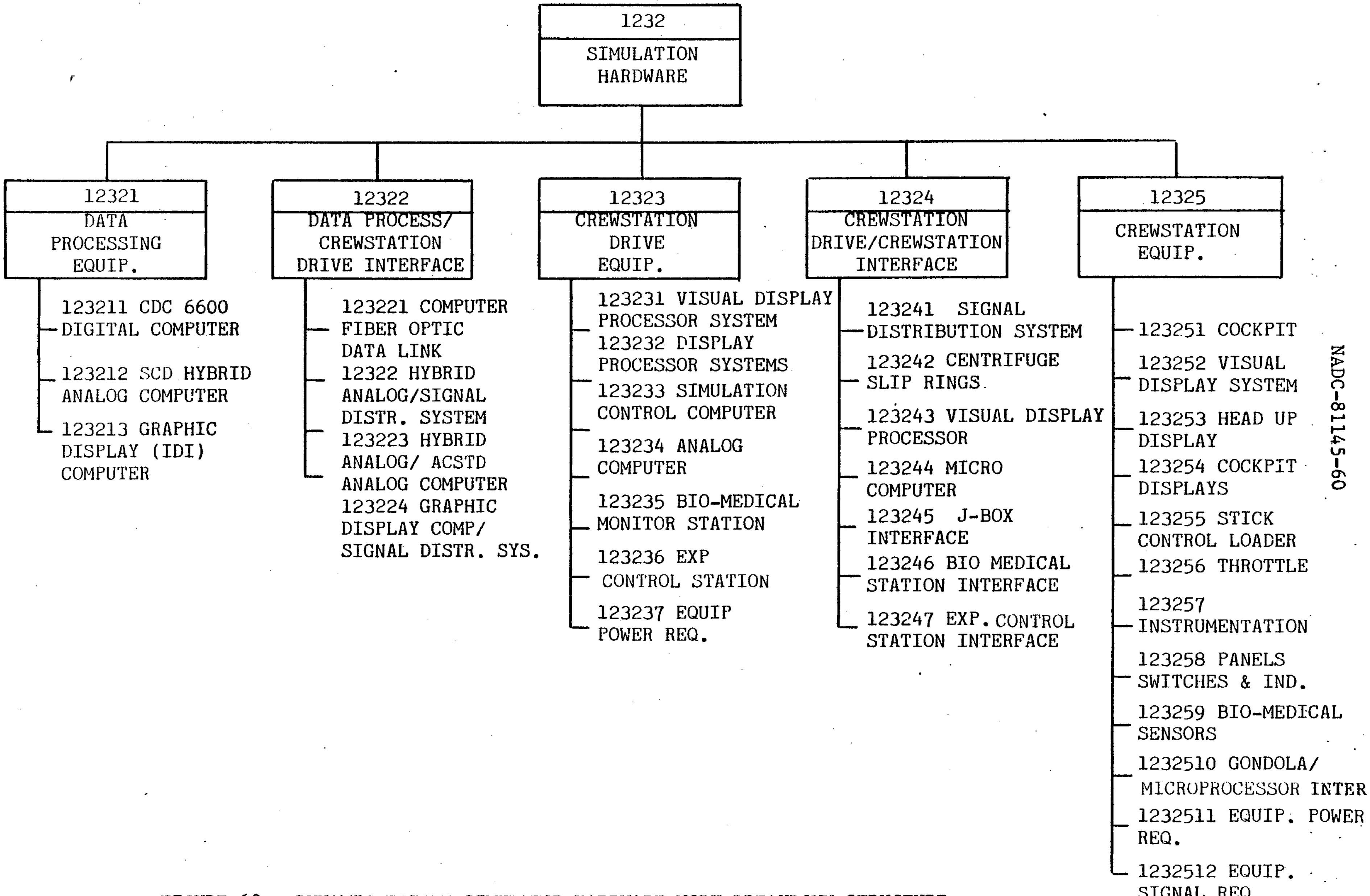


FIGURE 60. DYNAMIC FLIGHT SIMULATOR HARDWARE WORK BREAKDOWN STRUCTURE

4.0 Critical Issues

This section of the report discusses various critical issues or problem areas that will require satisfactory solutions to provide for a successful program. Although these issues are critical in terms of their impact on the program, none is felt to be insurmountable. They have been identified here in order to direct attention to the areas which will require additional emphasis during the course of the program.

4.1 Management Issues

4.1.1 System Integration Plan

A detailed laboratory and centrifuge hardware and software integration and checkout plan must be formulated to insure that the hardware equipment is compatible with the centrifuge system and that this hardware equipment is properly driven. This plan should include a system demonstration.

4.1.2 Experimental Procedures Plan

A detailed plan of experiments and experimental procedures must be developed. This plan would provide clear definitions of the F-14 issues and problems which require investigation on the DFS. The plan would also define precisely the maneuvering envelope of concern and the performance measures to be used to assess safely and effectively the proposed departure avoidance/recovery procedures. Finally the plan would provide a detailed schedule and definition of subject requirements for statistical reliability of the results.

4.2 Hardware Issues

4.2.1 Coordination of Overall System Timing

Coordination of the simulated aircraft flight controls, instrumentation, cockpit displays, the real-world visual display system, and the motion system is important so that the pilot does not perceive false cues. There are mechanical servo and computational delays associated with each of these systems. A delay of about 120 ms exists in the F-14 aircraft from the time a flight control input is initiated until a visual input is perceived.

The SP-2 Visual Display System's total lag from the real-time program's use of time corrected input data to the display of the resulting scene is never more than 100 ms. The display unit is updated every 25 ms for a day scene.

There is a 50 ms computational allowance for the CDC 6600 Digital Computer.

There is a 10 ms delay in sending or receiving data from the CDC 6600 computer to the Simulation control computer for each direction across the fiber optic link.

There is a 10 ms delay for inputing or outputing data from the Simulation Control computer.

There is a 50 ms computational allowance for the cockpit symbol generation units. The cockpit display unit is updated every 25 ms.

Several critical paths and the elector-mechanical servo, signal transmission, and computational delays associated with these paths are presented in Table XXXIV. The critical path is the driving of the centrifuge in the axis direction. Coordination of the SP-2 Visual Display and the centrifuge motion systems will have to be analyzed to provide an optimum visual/feel sensing relationship.

4.2.2 Visual Display System Compatibility

A Visual Display System study is required to insure the compatibility of the system with the centrifuge. Problems requiring analysis are:

1. The display unit must withstand accelerations in the order of 10-14 g.

2. The visual display system must be capable of transmitting video signals up to 250 feet via cable.

3. The visual display system must tolerate transmission of electronic signals through slip rings.

4. The display unit must meet the mounting constraints of the centrifuge gondolas internal dimensions.

An engineering services contract with the Redifon Simulation Company will aid in the analysis of these problems.

4.2.3 Feasibility of Second Visual Display

The original Dynamic Flight Simulator design envisioned as utilizing two SP-2 Visual Display System windows each with a 48 degree horizontal by 32 degree vertical field-of view. At this point in time it appears that utilizing two display windows will be an extremely difficult task. Each display unit requires 7 coax lines to drive the display. The forward window, head-up display, vertical display indicator, horizontal situation display, and the monitor camera utilize 16 of the available 19 coax lines. Each SP-2 Visual Display power supply weighs 100 lbs and required 11 amps of power. In addition each display window weighs 150 lbs.

The weight of the Dynamic Flight Simulator equipment located in the centrifuge gondola is becoming excessive and therefore the addition of the 250 lbs. for the second SP-2 Visual Display window and power supply is questionable. The additional power requirement is also questionable as is the space available for the second window.

TABLE XXXIV. DFS CRITICAL SIGNAL PATH TIME ESTIMATES

ELECTRO-MECHANICAL SERVO, SIGNAL TRANSMISSION, & COMPUTATIONAL DELAYS	FLIGHT CONTROL PITCH TO VISUAL DISPLAY SYSTEM PITCH (MS)	FLIGHT CONTROL PITCH TO COCKPIT DISPLAY PITCH (MS)	FLIGHT CONTROL PITCH TO INSTRUMENT PITCH (MS)	FLIGHT CONTROL PITCH TO MOTION PITCH (MS)	THROTTLE TO INCREASED ACCELERATION (MS)
STICK CONTROL LOADER SYSTEM TO IDI-V77	10	10	10	10	10
IDI V77 DATA INPUT/OUTPUT	10	10	10	10	10
IDI V77 TO CDC 6600	10	10	10	10	10
CDC 6600 COMPUTATIONS	50	50	50	50	50
CDC 6600 TO IDI V77	10	10	10	10	10
IDI V77 DATA INPUT/OUTPUT	10	10	10	10	10
VISUAL DISPLAY PROCESSOR COMP.	45 - 75	--	--	--	--
VISUAL DISPLAY PRESENTATION	25	--	--	--	--
SYMBOL GENERATOR COMP.	--	45 - 75	--	--	--
COCKPIT DISPLAY PRESENTATION	--	25	--	--	--
INSTRUMENTATION PRESENTATION	--	--	10	--	--
CENTRIFUGE DRIVE					
SERVO SYSTEM DELAYS					
PITCH/ROLL	--	--	--	120-200	--
CENTRIFUGE ARM	--	--	--	--	200-500
TOTAL TIME (MS)	170 MS (MIN) 200 MS (MAX)	170 MS (MIN) 200 MS (MAX)	110 MS	220 MS (MIN) 300 MS (MAX)	300 MS (MIN) 600 MS (MAX)

An analysis study is required to determine the practicality of utilizing the second SP-2 Visual Display window in the Dynamic Flight Simulator.

4.2.4 Fiber Optic Data Link

The Fiber Optic Data Link between the CDC 6600 (Bldg 1) and the Simulation Control Computer (Bldg 70) was installed 2 years ago but was never made fully operational. Recently, a contract has been let to complete the installation of the system and test it. This link must operate satisfactorily to enable the CDC 6600 to communicate with the SCC during the operation of the DFS.

4.2.5 Air Conditioning for the Experiment Control Station

The installation of the Simulation Control Computer and Visual Display processor of the Experiment Control Station will severly tax the present air conditioning system in that area (see Section 2.3.2.7). In order to maintain a cool environment for the computer equipment the area will have to be enclosed and cooling air redirected to supply the new room. This work will be performed under a Public Works Department Contract.

4.2.6 Air Conditioning for the Centrifuge Gondola Crewstation

The installation of heat-producing equipment in the Centrifuge Gondola (e.g., visual display, mircroprocessor) will necessitate additional air conditioning capacity (see Section 2.3.3.11). Several methods of accomplishing this are being investigated including:

(1) Supplying conditioned air to the gondola using the centrifuge's pneumatic slip rings.

(2) Upgrading the available gondola air conditioning system.

(3) Installing a dry ice heat-exchanger system in the gondola.

4.2.7 1553/Slip Ring compatibility

The centrifuge slip rings must be tested to determine if electrical noise generated by the slip rings will reduce the fidelity of 1553 multiplex transmissions. If this is the case, low-pass filtering may be added.

4.3 Software Issues

4.3.1 Centrifuge Control Algorithm

The accuracy of the centrifuge control algorithm developed for the DFS will have to be evaluated during dynamic runs of the centrifuge. The results will be purely subjective depending on the responses of the subject pilots.

Although initial analysis has shown that the false angular cues generated by the centrifuge can be diminished, the ultimate accuracy of response has yet to be determined.

4.3.2 Digital Control System for the Centrifuge

The concept of total digital control of the centrifuge instead of analog control is as yet untried. It is anticipated that the control system will require on-line modification before optimum efficiency is achieved.

4.3.3 F-14 Aero Data Checkout

The aerodynamic data package obtained for the F-14 may not be complete enough to provide realistic response in all pre-spin flight regimes. If additional data is required, it will have to be generated through wind tunnel modeling or through extrapolation of existing data.

4.3.4 Simulation Control Computer (V-77) Real-Time Operation

The operation of the Sperry Univac V77-600 minicomputer in real-time and in conjunction with the CDC-6600 has yet to be attempted. The coordination of data transmission may be a problem.

4.3.5 Manual Wing Sweep Data

As mentioned in Section 2.4.1.2.4.1.5 aerodynamic data for manual wing sweep outside of the wingsweep schedule is not presently available. In order to test spin recovery procedures using manual wing sweep, this data will have to be modeled through wind tunnel simulation. This approach is not planned in initial spin simulation experiments, however when the detailed Experimental Procedures are developed, it may become a desirable feature.

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5.1 Applicable MIL-STD References

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